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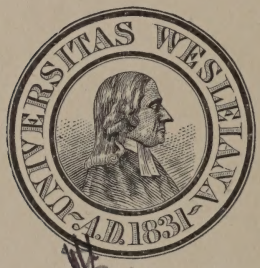

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AMERICAN SOCIETY
FOR
TESTING MATERIALS

ORGANIZED IN 1898
INCORPORATED IN 1902

LIST OF A.S.T.M. STANDARDS AND TENTATIVE STANDARDS

PRICE LIST OF PUBLICATIONS

As of September 2, 1930

ISSUED BY THE
AMERICAN SOCIETY FOR TESTING MATERIALS
1315 Spruce Street, Philadelphia, Pa.

THE American Society for Testing Materials is a national technical society of professional engineers, designers, testing experts, manufacturers, users and others interested in the properties of materials, organized for the purpose of "*the promotion of knowledge of the materials of engineering, and the standardization of specifications and the methods of testing.*" The work is done in two ways: first, through the presentation of scientific and technical data to the Society and its committees in the form of papers and discussions that are published in *Proceedings;* and second, through the activities of its 50 technical committees appointed to study the properties of the various materials. The committees are responsible for the development of standard specifications and methods of testing, which is a most important function of the Society. The committees function under definite regulations governing the organization of the committees and the procedure in preparing standards to insure adequate representation and voice of all parties interested in any standard. An even balance of producing and non-producing interests is maintained.

This pamphlet contains a complete list of all the standards and tentative standards developed through committee procedure and issued by the Society as of September 2, 1930, assembled in a sequence determined by the specific materials to which they apply. The standards and tentative standards are published collectively in the Book of A.S.T.M. Standards and Book of A.S.T.M. Tentative Standards, respectively, and are also available in separate pamphlet form.

For detailed prices of A.S.T.M. publications see page 28.

LIST OF A.S.T.M. STANDARDS AND TENTATIVE STANDARDS

As of September 2, 1930.

Standards, 427. Tentative Standards, 155. Total, 582.

The Standards are published collectively in the 1930 BOOK OF A.S.T.M. STANDARDS, Parts I and II. The Tentative Standards are published collectively in the 1930 BOOK OF A.S.T.M. TENTATIVE STANDARDS. Tentative Standards are also published in the annual Proceedings, Part I, in the year in which they were submitted or last revised as indicated by the final number of their serial designation.

For Price List of Publications, see page 28

The Standards and Tentative Standards are grouped according to the material to which they apply. Duplicate listings appear in italics.

Standards have been formally adopted by the Society. Tentative Standards are proposed standards published for one or more years with a view of eliciting criticism, of which the committee concerned will take due cognizance before recommending final action towards the adoption as Standard of such Tentative Standards.

The Standards and Tentative Standards are all copyrighted in the name of the American Society for Testing Materials. Permission to reprint any of them can be obtained only from the Executive Committee upon application to the Secretary-Treasurer.

In the serial designations prefixed to the titles in the following listing, the initial letter indicative of the general classification and the first number are fixed. The final numbers, 27, 28, etc. indicate the year of issue or adoption or, in the case of revision, the year of last revision. The letter "T" is appended to the designation of all Tentative Standards and in the following listing Tentative Standards are further distinguished from Standards by the abbreviation "Tent." In using Tentative Standards care should be taken to refer to the latest revision which may always be found in the Book of A.S.T.M. Tentative Standards issued yearly about October 15. In ordering Standards or Tentative Standards the complete serial designation should be stated, thus, A 1 – 30, A 65 – 26 T, etc.

A. FERROUS METALS

STEEL

Specifications

Steel Rails and Accessories

A 1 – 30. Spec. for Open-Hearth Carbon-Steel Rails.

A 2 – 27. Spec. for the Manufacture of Open-Hearth Steel Girder Rails of Plain, Grooved and Guard Types.

A 3 – 24. Spec. for Low-Carbon-Steel Splice Bars.
A 4 – 14. Spec. for Medium-Carbon-Steel Splice Bars.
A 5 – 14. Spec. for High-Carbon-Steel Splice Bars.
A 6 – 14. Spec. for Extra-High-Carbon-Steel Splice Bars.
A 49 – 21. Spec. for Quenched High-Carbon-Steel Splice Bars.
A 76 – 27. Spec. for Low-Carbon-Steel Track Bolts.
A 50 – 24. Spec. for Quenched Carbon-Steel Track Bolts.
A 51 – 21. Spec. for Quenched Alloy-Steel Track Bolts.
A 65 – 24. Spec. for Steel Track Spikes.
A 65 – 26 T. Tent. Spec. for Soft Steel Track Spikes.[1]
A 66 – 21. Spec. for Steel Screw Spikes.
A 67 – 30. Spec. for Steel Tie Plates.

Structural Steel

A 7 – 29. Spec. for Structural Steel for Bridges.
A 8 – 29. Spec. for Structural Nickel Steel.
A 94 – 29. Spec. for Structural Silicon Steel.
A 9 – 29. Spec. for Structural Steel for Buildings.
A 113 – 29. Spec. for Structural Steel for Locomotives and Cars.
A 12 – 21. Spec. for Structural Steel for Ships.
A 13 – 24. Spec. for Rivet Steel for Ships.

Boiler Steels

A 30 – 24. Spec. for Boiler and Firebox Steel for Locomotives.
A 70 – 27. Spec. for Boiler and Firebox Steel for Stationary Service.
A 129 – 30 T. Tent. Spec. for Open-Hearth Iron Plates of Flange Quality.
A 31 – 24. Spec. for Boiler Rivet Steel.
A 114 – 29 T. Tent. Spec. for Marine Boiler Steel Plates.

Steel for Welding

A 78 – 30. Spec. for Steel Plates of Structural Quality for Forge Welding.
A 89 – 30. Spec. for Steel Plates of Flange Quality for Forge Welding.

Strip Steel

A 109 – 27 T. Tent. Spec. for Cold-Rolled Strip Steel.

Concrete Reinforcement Steel

A 15 – 30. Spec. for Billet-Steel Concrete Reinforcement Bars.
A 16 – 14. Spec. for Rail-Steel Concrete Reinforcement Bars.
A 82 – 27. Spec. for Cold-Drawn Steel Wire for Concrete Reinforcement.

Bar Steels

A 107 – 30. Spec. for Commercial Quality Hot-Rolled Bar Steels.
A 108 – 30. Spec. for Commercial Cold-Finished Bar Steels and Cold-Finished Shafting.

Spring Steel and Springs

A 14 – 27. Spec. for Carbon-Steel Bars for Railway Springs.
A 68 – 27. Spec. for Carbon-Steel Bars for Railway Springs with Special Silicon Requirements.
A 58 – 27. Spec. for Carbon-Steel Bars for Vehicle and General Purpose Springs.

[1] To replace, when adopted, the present Standard Specifications for Steel Track Spikes (A.S.T.M. Designation: A 65 – 24).

A 59 – 27. Spec. for Silico-Manganese-Steel Bars for Railway Springs.
A 60 – 27. Spec. for Chrome-Vanadium-Steel Bars for Railway Springs.
A 61 – 16. Spec. for Helical Steel Springs for Railways.
A 62 – 16. Spec. for Elliptical Steel Springs for Railways.
A 125 – 29 T. Tent. Spec. for Heat-Treated Carbon-Steel Helical Springs.

Steel Blooms, Forgings and Axles

A 17 – 29. Spec. for Carbon-Steel and Alloy-Steel Blooms, Billets and Slabs for Forgings.
A 18 – 30. Spec. for Carbon-Steel and Alloy-Steel Forgings.
A 19 – 27. Spec. for Quenched-and-Tempered Carbon-Steel Axles, Shafts, and Other Forgings for Locomotives and Cars.
A 63 – 27. Spec. for Quenched-and-Tempered Alloy-Steel Axles, Shafts, and Other Forgings for Locomotives and Cars.
A 20 – 29 T. Tent. Spec. for Carbon-Steel Forgings for Locomotives.
A 21 – 27. Spec. for Carbon-Steel Car and Tender Axles.
A 22 – 21. Spec. for Cold-Rolled Steel Axles.

Steel Chain

A 77 – 28 T. Tent. Spec. for Electric Cast-Steel Stud-Link Anchor Chain.
A 56 – 30. Spec. for Iron and Steel Chain.

Steel Wheels and Tires

A 25 – 24. Spec. for Wrought Solid Carbon-Steel Wheels for Electric Railway Service.
A 57 – 29. Spec. for Wrought Solid Carbon-Steel Wheels for Steam Railway Service.
A 26 – 16. Spec. for Steel Tires.

Steel Castings

A 27 – 24. Spec. for Steel Castings.
A 87 – 27. Spec. for Carbon-Steel Castings for Railroads.
A 128 – 30 T. Tent. Spec. for Austenitic Manganese Steel Castings.
A 95 – 29. Spec. for Carbon-Steel Castings for Valves, Flanges, and Fittings for High-Temperature Service.

Steel Tubes and Pipe

A 83 – 30. Spec. for Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler Tubes.
A 105 – 28. Spec. for Forged or Rolled Steel Pipe Flanges for High-Temperature Service.
A 106 – 29. Spec. for Lap-Welded and Seamless Steel Pipe for High-Temperature Service.
A 53 – 30. Spec. for Welded and Seamless Steel Pipe.
A 120 – 28 T. Tent. Spec. for Black and Hot-Dipped Zinc-Coated (Galvanized) Welded and Seamless Steel Pipe for Ordinary Uses.

Tool Steels

A 71 – 26. Spec. for Carbon Tool Steel.
A 92 – 26. Spec. for High-Speed Tool Steel.
A 115 – 28. Spec. for Alloy Tool Steel.

Steel for High-Temperature Service

A 95 – 29. Spec. for Carbon-Steel Castings for Valves, Flanges, and Fittings for High-Temperature Service.
A 96 – 27. Spec. for Alloy-Steel Bolting Material for High-Temperature Service.
A 105 – 28. Spec. for Forged or Rolled Steel Pipe Flanges for High-Temperature Service.
A 106 – 29. Spec. for Lap-Welded and Seamless Steel Pipe for High-Temperature Service.

Zinc-Coated Articles

A 123 – 30. Spec. for Zinc (Hot-Galvanized) Coatings on Structural Steel Shapes, Plates and Bars and Their Products.
A 93 – 27. Spec. for Zinc-Coated (Galvanized) Sheets.
A 120 – 28 T. *Tent. Spec. for Black and Hot-Dipped Zinc-Coated (Galvanized) Welded and Seamless Steel Pipe for Ordinary Uses.*
A 111 – 30. Spec. for Zinc-Coated (Galvanized) Iron or Steel Telephone and Telegraph Line Wire.
A 12 – 30. Spec. for Zinc-Coated (Galvanized) Iron or Steel Tie Wires.
A 16 – 30. Spec. for Zinc-Coated (Galvanized) Farm-Field and Railroad Right-of-Way Wire Fencing.
A 111 – 30. Spec. for Zinc-Coated Chain-Link Fence Fabric Galvanized After Weaving.
A 118 – 30 T. Tent. Spec. for Zinc-Coated Chain-Link Fence Fabric Galvanized Before Weaving.
A 121 – 30. Spec. for Zinc-Coated (Galvanized) Barb Wire.
A 122 – 30. Spec. for Zinc-Coated (Galvanized) Steel Wire Strand.

METHODS

A 130 – 30. Methods of Sampling Rolled and Forged Steel Products for Check Analysis
A 33 – 24. Methods of Chemical Analysis of Plain Carbon Steel.
A 55 – 24. Methods of Chemical Analysis of Alloy Steels.
A 90 – 30. Methods of Determining Weight of Coating on Zinc-Coated Articles.
A 91 – 24. Methods of Determining Weight of Coating on Tin, Terne, and Lead-Coated Sheets.
A 34 – 28. Methods of Test for Magnetic Properties of Iron and Steel.
A 110 – 30. Methods of Testing Zinc-Coated (Galvanized) Iron and Steel Wire and Wire Products.
E 3 – 24. *Methods of Metallographic Testing of Iron and Steel.*
E 8 – 27 T. *Tent. Methods of Tension Testing of Metallic Materials.*
E 9 – 27 T. *Tent. Methods of Compression Testing of Metallic Materials.*
E 10 – 27. *Methods of Brinell Hardness Testing of Metallic Materials.*

RECOMMENDED PRACTICES

A 35 – 24. Recommended Practice for Annealing of Miscellaneous Rolled and Forged Carbon-Steel Objects.
A 36 – 24. Recommended Practice for Heat Treatment of Carbon-Steel Castings.
A 37 – 27. Recommended Practice for Carburizing and Heat Treatment of Carburized Objects.
E 14 – 30. T. Tent. Recommended Practice for Thermal Analysis of Steel.
E 15 – 29. Recommended Practice for Radiographic Testing of Metal Castings.

DEFINITIONS

A 119 – 30. Def. of Terms Relating to Heat Treatment Operations (Especially as Related to Ferrous Alloys).
A 127 – 30 T. Tent. Def. of Terms, with Units and Symbols, Relating to Magnetic Testing.

WROUGHT IRON

SPECIFICATIONS

A 72 – 30. Spec. for Welded Wrought-Iron Pipe.
A 83 – 30. Spec. for Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler Tubes.
A 84 – 30. Spec. for Staybolt, Engine-Bolt and Extra-Refined Wrought-Iron Bars.
A 86 – 30. Spec. for Hollow Rolled Staybolt Iron.
A 41 – 30. Spec. for Refined Wrought-Iron Bars.
A 85 – 27. Spec. for Common Iron Bars.
A 42 – 30. Spec. for Wrought-Iron Plates.
A 73 – 30. Spec. for Wrought-Iron Rolled or Forged Blooms and Forgings for Locomotives and Cars.
A 56 – 30. Spec. for Iron and Steel Chain.

DEFINITIONS

A 81 – 30. Def. of Terms Relating to Wrought-Iron Specifications.

PIG IRON, CAST IRON, AND FINISHED CASTINGS

SPECIFICATIONS

A 43 – 24. Spec. for Foundry Pig Iron.
A 44 – 04. Spec. for Cast-Iron Pipe and Special Castings.
A 74 – 29. Spec. for Cast-Iron Soil Pipe and Fittings.
A 45 – 14. Spec. for Cast-Iron Locomotive Cylinders.
A 46 – 24. Spec. for Chilled Cast-Iron Wheels.
A 46 – 30 T. Tent. Spec. for Chilled-Tread Cast-Iron Wheels.[1]
A 47 – 30. Spec. for Malleable Castings.
A 48 – 29. Spec. for Gray-Iron Castings.
A 88 – 29. Spec. for High-Test Gray-Iron Castings.

[1] To replace, when adopted, the present Standard Specifications for Chilled Cast-Iron Wheels (A.S.T.M. Designation: A 46 – 24).

A 126 – 30. Spec. for Gray-Iron Castings for Valves, Flanges and Pipe Fittings.
A 124 – 29. Spec. for the Arbitration Test Bar and Tension Test Specimen for Cast Iron.

METHODS

A 64 – 27. Methods of Sampling and Chemical Analysis of Pig and Cast Iron.

RECOMMENDED PRACTICE

E 15 – 29. Recommended Practice for Radiographic Testing of Metal Castings.

FERRO-ALLOYS

SPECIFICATIONS

A 97 – 27. Spec. for Tungsten Powder.
A 98 – 27. Spec. for Spiegeleisen.
A 99 – 27. Spec. for Ferro-Manganese.
A 100 – 27. Spec. for Ferro-Silicon.
A 101 – 27. Spec. for Ferro-Chromium.
A 102 – 27. Spec. for Ferro-Vanadium.

METHODS

A 103 – 27. Methods of Sampling Ferro-Alloys.
A 104 – 27. Methods of Chemical Analysis of Ferro-Alloys.

B. NON-FERROUS METALS

SPECIFICATIONS

Ingot Copper

B 4 – 27. Spec. for Lake Copper Wire Bars, Cakes, Slabs, Billets, Ingots, and Ingot Bars.
B 5 – 27. Spec. for Electrolytic Copper Wire Bars, Cakes, Slabs, Billets, Ingots, and Ingot Bars.
B 72 – 28 T. Tent. Spec. for Fire-Refined Copper Other Than Lake.

Zinc

B 6 – 18. Spec. for Slab Zinc (Spelter).
B 69 – 29. Spec. for Rolled Zinc.

Lead

B 29 – 23. Spec. for Pig Lead.

Nickel

B 39 – 22. Spec. for Nickel.

Aluminum and Aluminum Alloys

B 37 – 26. Spec. for Aluminum for Use in the Manufacture of Iron and Steel.
B 24 – 29. Spec. for Aluminum Ingots for Remelting.
B 25 – 29. Spec. for Aluminum Sheet.
B 78 – 30 T. Tent. Spec. for Aluminum-Alloy (Duralumin) Sheet.

B 79 – 30 T. Tent. Spec. for Aluminum-Manganese Alloy Sheet.
B 58 – 30 T. Tent. Spec. for Aluminum-Base Casting Alloys in Ingot Form.
B 26 – 30 T. Tent. Spec. for Aluminum-Base Alloy Castings.
B 80 – 30 T. Tent. Spec. for Magnesium-Base Alloy Castings.
B 59 – 28. *Spec. for Aluminum Bronze Castings.*

Deoxidizers

B 37 – 26. *Spec. for Aluminum for Use in the Manufacture of Iron and Steel.*
B 51 – 27. Spec. for Phosphor Tin.
B 52 – 27. Spec. for Phosphor Copper.
B 53 – 27. Spec. for Silicon Copper.

Copper Wire and Cable

B 49 – 26. Spec. for Hot-Rolled Copper Rods for Wire Drawing.
*B 1 – 27. Spec. for Hard-Drawn Copper Wire.
B 2 – 27. Spec. for Medium Hard-Drawn Copper Wire.
*B 3 – 27. Spec. for Soft or Annealed Copper Wire.
*B 33 – 21. Spec. for Tinned Soft or Annealed Copper Wire for Rubber Insulation.
B 48 – 27. Spec. for Soft Rectangular Copper Wire.
B 8 – 27. Spec. for Bare Concentric-Lay Copper Cable: Hard, Medium-Hard, or Soft.
B 9 – 30. Spec. for Bronze Trolley Wire.
B 47 – 30. Spec. for Round and Grooved Hard-Drawn Copper Trolley Wire.
D 27 – 28 T. *Tent. Spec. for Insulated Wire and Cable: 30-per-cent Hevea Rubber.*

Brass and Bronze

B 10 – 18. Spec. for the Alloy: Copper 88 per cent; Tin 10 per cent; Zinc 2 per cent.
B 60 – 28. Spec. for Sand Castings of the Alloy: Copper 88 per cent; Tin 8 per cent; Zinc 4 per cent.
B 74 – 28 T. Tent. Spec. for Sand Castings of the Alloy: Copper 80 per cent; Tin 10 per cent; Lead 10 per cent.
B 31 – 21. Spec. for Bronze Bearing Metal in Ingot Form.
B 22 – 21. Spec. for Bronze Bearing Metals for Turntables and Movable Railroad Bridges.
B 66 – 28. Spec. for Bronze Castings in the Rough for Locomotive Wearing Parts.
B 30 – 30 T. Tent. Spec. for Copper Base Alloys in Ingot Form for Sand Castings.
B 61 – 28. Spec. for Steam or Valve Bronze Sand Castings.
B 62 – 28. Spec. for Composition Brass or Ounce Metal Sand Castings.
B 65 – 28. Spec. for Yellow Brass Sand Castings for General Purposes.
B 7 – 27. Spec. for Manganese-Bronze Ingots for Sand Castings.
B 54 – 27. Spec. for Manganese-Bronze Sand Castings.
B 59 – 28. Spec. for Aluminum Bronze Castings.

* Approved as "American Standard" by the American Standards Association.

Solder Metal

†B	32 – 21.	Spec. for Solder Metal.
B	64 – 28.	Spec. for Brazing Solder.
B	73 – 29.	Spec. for Silver Solders.

White Metal

B	23 – 26.	Spec. for White Metal Bearing Alloys (known commercially as "Babbitt Metal").
B	67 – 28.	Spec. for Car and Tender Journal Bearings, Lined.

Copper and Brass Plates, Tubes, Rods, etc.

B	11 – 18.	Spec. for Copper Plates for Locomotive Fireboxes.
B	12 – 21.	Spec. for Copper Bars for Locomotive Staybolts.
B	13 – 18.	Spec. for Seamless Copper Boiler Tubes.
B	14 – 18.	Spec. for Seamless Brass Boiler Tubes.
B	44 – 29.	Spec. for Seamless Admiralty Condenser Tubes and Ferrule Stock.
B	55 – 25.	Spec. for Seamless 70–30 Brass Condenser Tubes and Ferrule Stock.
B	56 – 25.	Spec. for Seamless Muntz Metal Condenser Tubes and Ferrule Stock.
B	57 – 27.	Spec. for Muntz Metal Condenser Tube Plates.
B	42 – 24.	Spec. for Copper Pipe, Standard Sizes.
B	43 – 24.	Spec. for Brass Pipe, Standard Sizes.
B	75 – 30.	Spec. for Seamless Copper Tubes.
B	68 – 30 T.	Tent. Spec. for Seamless Copper Tubing, Bright Annealed.
†B	15 – 18.	Spec. for Brass Forging Rod.
B	16 – 29.	Spec. for Free-Cutting Brass Rod for Use in Screw Machines.
B	19 – 29.	Spec. for Cartridge Brass.
B	20 – 29.	Spec. for Cartridge Brass Disks.
B	21 – 29.	Spec. for Naval Brass Rods for Structural Purposes.
B	36 – 27.	Spec. for Sheet High Brass.
B	50 – 29.	Spec. for Non-Ferrous Insect Screen Cloth.

METHODS

†B	34 – 20.	Methods of Battery Assay of Copper.
B	38 – 21.	Methods of Chemical Analysis of Slab Zinc (Spelter).
B	35 – 24.	Methods of Chemical Analysis of Pig Lead.
B	41 – 23.	Methods of Chemical Analysis of Nickel.
B	40 – 28 T.	Tent. Methods of Chemical Analysis of Aluminum and Light Aluminum Alloys.
†B	18 – 21.	Methods of Chemical Analysis of Alloys of Lead, Tin, Antimony and Copper.
†B	27 – 19.	Methods of Chemical Analysis of Manganese Bronze.
†B	28 – 19.	Methods of Chemical Analysis of Gun Metal.
B	45 – 27.	Methods of Chemical Analysis of Brass Ingots and Sand Castings.
B	46 – 27.	Methods of Chemical Analysis of Bronze Bearing Metal.

† Approved as "American Tentative Standard" by the American Standards Association.

B 71 – 29 T. Tent. Methods of Chemical Analysis of Metallic Materials for Electrical Heating.
B 63 – 29. Method of Test for Resistivity of Metallic Materials for Resistors.
B 70 – 30. Method of Test for Change of Resistance with Temperature of Metallic Materials for Electrical Heating.
B 76 – 29 T. Tent. Accelerated Life Test for Metallic Materials for Electrical Heating.
B 77 – 30 T. Tent. Method of Test for Thermoelectric Power.
A 90 – 30. Methods of Determining Weight of Coating on Zinc-Coated Articles.
A 91 – 24. Method of Determining Weight of Coating on Tin, Terne, and Lead-Coated Sheets.
E 5 – 27. Methods of Metallographic Testing of Non-Ferrous Metals and Alloys.
E 8 – 27 T. Tent. Methods of Tension Testing of Metallic Materials.
E 9 – 27 T. Tent. Methods of Compression Testing of Metallic Materials.
E 10 – 27. Methods of Brinell Hardness Testing of Metallic Materials.

RECOMMENDED PRACTICE

E 15 – 29. Recommended Practice for Radiographic Testing of Metal Castings.

C. CEMENT, LIME, GYPSUM, CONCRETE, AND CLAY PRODUCTS

CEMENT

SPECIFICATIONS

C 9 – 30. Spec. for Portland Cement.
C 9 – 16 T. Tent. Spec. and Tests for Compressive Strength of Portland-Cement Mortars.[1]
C 74 – 30 T. Tent. Spec. for High-Early-Strength Portland Cement.
C 10 – 09. Spec. for Natural Cement.

METHODS

C 77 – 30. Methods of Testing Cement.

LIME

SPECIFICATIONS

C 5 – 26. Spec. for Quicklime for Structural Purposes.
C 6 – 24. Spec. for Hydrated Lime for Structural Purposes.
C 45 – 25. Spec. for Quicklime and Hydrated Lime for Use in the Cooking of Rags for the Manufacture of Paper.
C 46 – 27. Spec. for Quicklime for Use in the Manufacture of Sulfite Pulp.
C 47 – 27. Spec. for Hydrated Lime for the Manufacture of Varnish.
C 48 – 24. Spec. for Quicklime and Hydrated Lime for Use in the Textile Industry.

[1] To be added, when adopted, to the present Standard Specifications for Portland Cement (A.S.T.M. Designation: C 9 – 30), and the Standard Methods of Testing Cement (A.S.T.M. Designation: C 77 – 30).

C 49 – 24. Spec. for Quicklime and Hydrated Lime for the Manufacture of Silica Brick.
C 53 – 27. Spec. for Quicklime for Use in Water Treatment.
C 54 – 27. Spec. for Hydrated Lime for Use in Water Treatment.
C 66 – 27 T. Tent. Spec. for Sand for Use in Lime Plaster.

METHODS

C 25 – 29. Methods of Chemical Analysis of Limestone, Quicklime and Hydrated Lime.
C 50 – 27. Methods of Sampling, Inspection, Packing and Marking of Quicklime and Lime Products.

DEFINITIONS

C 51 – 28. Def. of Terms Relating to Lime.

GYPSUM

SPECIFICATIONS

C 22 – 25. Spec. for Gypsum.
C 23 – 30. Spec. for Calcined Gypsum.
C 72 – 30. Spec. for Calcined Gypsum for Use in the Preparation of Dental Plasters.
C 61 – 30. Spec. for Keene's Cement.
C 28 – 30. Spec. for Gypsum Plasters.
C 59 – 30. Spec. for Gypsum Molding Plaster.
C 60 – 30. Spec. for Gypsum Pottery Plaster.
C 35 – 30. Spec. for Gypsum Plastering Sand.
C 36 – 25. Spec. for Gypsum Wall Board.
C 37 – 30. Spec. for Gypsum Plaster Board.
C 79 – 30 T. Tent. Spec. for Gypsum Sheathing Board.
C 52 – 27. Spec. for Gypsum Partition Tile or Block.

METHODS

C 26 – 30. Methods of Testing Gypsum and Gypsum Products.

DEFINITIONS

C 11 – 28. Def. of Terms Relating to the Gypsum Industry.
C 11 – 29 T. Tent. Def. of Terms Relating to the Gypsum Industry.[1]

CONCRETE AND CONCRETE AGGREGATES

SPECIFICATIONS

C 33 – 28 T. Tent. Spec. for Concrete Aggregates.
D 57 – 20. *Spec. for Materials for Cement Grout Filler for Brick and Stone Block Pavements.*
D 58 – 24. *Spec. for Materials for Cement Mortar Bed for Brick, Stone Block, Wood Block, Asphalt Block and Other Block Pavements.*

[1] To be added, when adopted, to the present Standard Definitions of Terms Relating to the Gypsum Industry (A.S.T.M. Designation: C 11 – 28).

METHODS

C 31 – 27.	Methods of Making and Storing Compression Test Specimens of Concrete in the Field.
C 39 – 27.	Methods of Making Compression Tests of Concrete.
C 78 – 30 T.	Tent. Laboratory Method of Making Flexure Tests of Concrete Using a Simple Beam with Center Loading.
C 42 – 27.	Method of Securing Specimens of Hardened Concrete from the Structure.
C 29 – 27.	Method of Test for Unit Weight of Aggregate for Concrete.
†C 30 – 22.	Method of Test for Determination of Voids in Fine Aggregate for Concrete.
C 40 – 27.	Method of Test for Organic Impurities in Sands for Concrete.
C 41 – 24.	Method of Test for Sieve Analysis of Aggregates for Concrete.
C 68 – 30.	Method of Test for Approximate Apparent Specific Gravity of Fine Aggregate.
C 69 – 30.	Method of Test for Approximate Percentage of Voids in Inundated Fine Aggregate.
C 70 – 30.	Method of Test for Surface Moisture in Fine Aggregate.
D 30 – 18.	*Method of Test for Apparent Specific Gravity of Coarse Aggregates.*
D 55 – 25.	*Methods of Test for Apparent Specific Gravity of Sand, Stone and Slag Screenings, and Other Fine Non-Bituminous Highway Materials.*
D 136 – 28.	*Method of Decantation Test for Sand and Other Fine Aggregates.*
D 138 – 26 T.	*Tent. Method of Test for Consistency of Portland-Cement Concrete.*

DEFINITIONS

C 58 – 28.	Def. of the Term Sand.
C 58 – 28 T.	Tent. Def. of the Term Aggregate.[1]
E 13 – 28 T.	*Tent. Def. of the Term Screen (Sieve).*

RULES

C 44 – 22 T.	Tent. Rules for Inspection of Concrete and Reinforced Concrete Work.

BRICKS AND REFRACTORIES

SPECIFICATIONS

C 62 – 30.	Spec. for Building Brick (Made from Clay or Shale).
C 55 – 28 T.	Tent. Spec. for Concrete Building Brick.
C 73 – 30.	Spec. for Sand-Lime Building Brick.
C 7 – 30.	Spec. for Paving Brick.
C 32 – 24.	Spec. for Clay Sewer Brick.
C 63 – 28.	Spec. for Clay Fire Brick for Malleable Furnaces with Removable Bungs and for Annealing Ovens.
C 64 – 28.	Spec. for Clay Fire Brick for Stationary Boiler Service.
C 65 – 28.	Spec. for Clay Fire Brick for Marine Boiler Service.

† Approved as "American Tentative Standard" by the American Standards Association.

[1] To be added, when adopted, to the present Standard Definition of the Term Sand (A.S.T.M. Designation: C 58 – 28).

METHODS

C 67 – 30 T. Tent. Methods of Testing Brick (Compression, Flexure and Absorption).
C 16 – 20. Method of Test for Refractory Materials Under Load at High Temperatures.
C 20 – 20. Method of Test for Porosity and Permanent Volume Changes in Refractory Materials.
C 24 – 28. Method of Test for Softening Point of Fire-Clay Brick.
C 38 – 27 T. Tent. Method of Test for Resistance of Fire-Clay Brick to Thermal Spalling Action.
C 18 – 21. Methods of Ultimate Chemical Analysis of Refractory Materials, Including Chrome Ores and Chrome Brick.

DEFINITIONS

C 27 – 28. Def. for Clay Refractories.
C 71 – 28. Def. of Terms Relating to Refractories.
C 71 – 30 T. Tent. Def. of Terms Relating to Refractories.[1]

PIPE AND DRAIN TILE

SPECIFICATIONS

C 13 – 24. Spec. for Clay Sewer Pipe.
C 14 – 24. Spec. for Cement-Concrete Sewer Pipe.
*C 4 – 24. Spec. for Drain Tile.
C 75 – 30 T. Tent. Spec. for Reinforced-Concrete Pipe.
C 76 – 30 T. Tent. Spec. for Reinforced-Concrete Culvert Pipe.

DEFINITIONS

C 8 – 24. Def. of Terms Relating to Sewer Pipe.

RECOMMENDED PRACTICE

C 12 – 19. Recommended Practice for Laying Sewer Pipe.

HOLLOW TILE

SPECIFICATIONS

C 34 – 30. Spec. and Tests for Hollow Burned-Clay Load-Bearing Wall Tile.
C 56 – 30. Spec. and Tests for Hollow Burned-Clay Fireproofing, Partition and Furring Tile.
C 57 – 30. Spec. and Tests for Hollow Burned-Clay Floor Tile.

DEFINITIONS

C 43 – 24. Def. of Terms Relating to Hollow Tile.

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* Approved as "American Standard" by the American Standards Association.

[1] To be added, when adopted, to the present Standard Definitions of Terms Relating to Refractories (A.S.T.M. Designation: C 71 – 28).

MISCELLANEOUS SUBJECTS

SPECIFICATIONS

†C 19 – 26 T. Tent. Spec. for Fire Tests of Building Construction and Materials.
E 11 – 26. *Spec. for Sieves for Testing Purposes.*

METHODS

D 116 – 30. *Methods of Testing Electrical Porcelain.*

DEFINITIONS

E 12 – 27. *Def. of Terms Relating to Specific Gravity.*
E 13 – 28 T. *Tent. Def. of the Term Screen (Sieve).*

D. MISCELLANEOUS MATERIALS

PRESERVATIVE COATINGS

SPECIFICATIONS

D 234 – 28. Spec. for Raw Linseed Oil.
D 260 – 28 T. Tent. Spec. for Boiled Linseed Oil.
D 12 – 25 T. Tent. Spec. for Raw Tung Oil.
D 124 – 22 T. Tent. Spec. for Soya Bean Oil, Raw or Refined.
D 125 – 23. Spec. for Perilla Oil, Raw or Refined.
D 235 – 26 T. Tent. Spec. for Petroleum Spirits (Mineral Spirits).
D 13 – 26. Spec. for Gum Spirits of Turpentine and Steam-Distilled Wood Turpentine.
D 236 – 27. Spec. for Destructively Distilled Wood Turpentine.
D 317 – 30 T. Tent. Spec. for Glazier's Putty.
D 207 – 29 T. Tent. Spec. for Dry Bleached Shellac.
D 237 – 29 T. Tent. Spec. for Orange Shellac.
D 79 – 24. Spec. for Zinc Oxide.
D 80 – 24. Spec. for Leaded Zinc Oxide.
D 81 – 24. Spec. for Basic Carbonate White Lead.
D 82 – 24. Spec. for Basic Sulfate White Lead.
D 83 – 24. Spec. for Red Lead.
D 84 – 27. Spec. for Mineral Iron Oxide.
D 85 – 27. Spec. for Ocher.
D 208 – 26. Spec. for Lithopone.
D 209 – 30. Spec. for Lampblack.
D 210 – 30. Spec. for Bone Black.
D 211 – 27. Spec. for Chrome Yellow.
D 212 – 27. Spec. for Pure Chrome Green.
D 213 – 27. Spec. for Reduced Chrome Green.
D 263 – 28. Spec. for Chrome Oxide Green.
D 261 – 28. Spec. for Prussian Blue.
D 262 – 28. Spec. for Ultramarine Blue.
D 264 – 28. Spec. for Commercial Para Red
D 266 – 28 T. Tent. Spec. for Aluminum Powder for Paints (Aluminum Bronze Powder).

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† Approved as "American Tentative Standard" by the American Standards Association.

D 267 – 28 T. Tent. Spec. for Gold Bronze Powder.
D 277 – 28 T. Tent. Spec. for the Toxic Ingredients in Anti-Fouling Paints.
D 301 – 30 T. Tent. Spec. for Soluble Nitrocellulose.
D 318 – 30 T. Tent. Spec. for Amyl Acetate (Synthetic).
D 319 – 30 T. Tent. Spec. for Amyl Alcohol (Synthetic).
D 302 – 30 T. Tent. Spec. for Ethyl Acetate (85 to 88 per cent Grade).
D 321 – 30 T. Tent. Spec. for Ethyl Lactate (Synthetic).
D 303 – 30 T. Tent. Spec. for Normal Butyl Acetate (88 to 92 per cent Grade).
D 304 – 30 T. Tent. Spec. for Butanol (Normal Butyl Alcohol).
D 320 – 30 T. Tent. Spec. for Butyl Propionate (90 to 93 per cent Grade).

METHODS

D 233 – 26. Methods of Sampling and Testing Turpentine.
D 153 – 27. Methods of Test for Specific Gravity of Pigments.
D 185 – 29. Methods of Test for Coarse Particles in Dry Pigments and Coarse Particles and Skins in Mixtures of Pigments and Vehicles.
D 278 – 28 T. Tent. Method of Test for Alkalinity or Acidity of Pigments.
D 279 – 29 T. Tent. Methods of Test for Bleeding of Pigments.
D 280 – 28 T. Tent. Methods of Test for Hygroscopic Moisture (and Other Matter Volatile Under the Test Conditions) in Pigments.
D 281 – 28 T. Tent. Method of Test for Oil Absorption of Pigments.
D 154 – 28. Methods of Testing Oleo-Resinous Varnishes.
D 29 – 29 T. Tent. Methods of Sampling and Testing Shellac.
D 268 – 30 T. Tent. Methods of Sampling and Testing Lacquer Solvents and Diluents.
†D 56 – 21. Method of Test for Flash Point of Volatile Flammable Liquids.
*D 34 – 30. Methods of Routine Analysis of White Pigments.
D 215 – 29. Methods of Routine Analysis of White Linseed Oil Paints.
*D 49 – 29. Methods of Routine Analysis of Dry Red Lead.
D 50 – 27. Methods of Routine Analysis of Yellow, Orange, Red and Brown Pigments Containing Iron and Manganese.
D 126 – 27. Methods of Routine Analysis of Yellow and Orange Pigments Containing Chromium Compounds, Blue Pigments and Chrome Green.
D 186 – 29. Methods of Routine Analysis of Titanium Pigments.
D 283 – 29. Method of Routine Analysis of Dry Cuprous Oxide.
D 284 – 29. Method of Routine Analysis of Dry Mercuric Oxide.
D 305 – 29 T. Tent. Method of Routine Determination of Acetone Extract in Dry Lampblack and Dry Bone Black.
D 306 – 29 T. Tent. Method of Test for Determination of Polishing Lubricant in Aluminum Powder for Paints (Aluminum Bronze Powder).
D 307 – 30. Method of Analysis for the Color Characteristics of Paints in Terms of Fundamental Physical Units.

DEFINITIONS

D 16 – 24. Def. of Terms Relating to Paint Specifications.

* Approved as "American Standard" by the American Standards Association.
† Approved as "American Tentative Standard" by the American Standards Association.

NAVAL STORES

METHOD

D 269 – 30. Method of Test for Determination of Toluol Insoluble Matter in Rosin (Chiefly Sand, Chips, Dirt and Bark).

PETROLEUM PRODUCTS AND LUBRICANTS

See also Road Materials and Waterproofing and Roofing Materials

METHODS

*D 206 – 25. Abridged Volume Correction Table for Petroleum Oils.
D 270 – 30 T. Tent. Methods of Sampling Petroleum and Petroleum Products.
*D 128 – 27. Method of Analysis of Grease.
†*D 139 – 27.* *Method of Float Test for Bituminous Materials.*
D 187 – 30. Method of Test for Burning Quality of Kerosine Oils.
D 219 – 30. Method of Test for Burning Quality of Long-Time Burning Oil for Railway Use.
D 239 – 30. Method of Test for Burning Quality of Mineral Seal Oil.
D 189 – 30. Method of Test for Carbon Residue of Petroleum Products (Conradson Carbon Residue).
D 97 – 30. Method of Test for Cloud and Pour Points of Petroleum Products.
†*D 4 – 27.* *Method of Test for the Determination of Bitumen.*
D 165 – 27. *Method of Test for the Determination of Proportion of Bitumen Soluble in Carbon Tetrachloride.*
D 155 – 23 T. Tent. Method of Test for Color of Lubricating Oils by Means of Union Colorimeter.
D 218 – 25 T. Tent. Method of Test for Color of Petrolatum by Means of Union Colorimeter.
D 156 – 23 T. Tent. Method of Test for Color of Refined Petroleum Oil by Means of Saybolt Chromometer.
D 322 – 30 T. Tent. Method of Test for Dilution of Crankcase Oil.
D 86 – 30. Method of Test for Distillation of Gasoline, Naphtha, Kerosine, and Similar Petroleum Products.
D 216 – 30. Method of Test for Distillation of Natural Gas Gasoline.
D 130 – 30. Method of Test for Detection of Free Sulfur and Corrosive Sulfur Compounds in Gasoline.
D 286 – 30. Method of Test for the Determination of Autogenous Ignition Temperatures.
D 117 – 27. *Methods of Testing Electrical Insulating Oils.*
D 308 – 29 T. Tent. Method of Test for Expressible Oil and Moisture in Paraffin Waxes.
D 285 – 30 T. Tent. Method of Test for Distillation of Crude Petroleum.
D 113 – 26 T. *Tent. Method of Test for Ductility of Bituminous Materials.*
D 56 – 21. *Method of Test for Flash Point of Volatile Flammable Liquids.*
*D 93 – 22. Method of Test for Flash Point by Means of the Pensky-Martens Closed Tester.
*D 92 – 24. Method of Test for Flash and Fire Points by Means of Open Cup.

* Approved as "American Standard" by the American Standards Association.
† Approved as "American Tentative Standard" by the American Standards Association.

D 287 – 30 T. Tent. Method of Test for Gravity of Petroleum and Petroleum Products by Means of the Hydrometer.

D 158 – 28. Methods of Testing Gas Oils (Gravity, Distillation, Sulfur, Carbon Residue, Pour Point, Viscosity, Water).

D 6 – 30. *Method of Test for Loss on Heating of Oil and Asphaltic Compounds.*

*D 87 – 22. Method of Test for Melting Point of Paraffin Wax.

†D 5 – 25. *Method of Test for Penetration of Bituminous Materials.*

D 127 – 30. Method of Test for Melting Point of Petrolatum.

†D 188 – 27 T. Tent. Method of Test for Neutralization Number of Petroleum Products and Lubricants.

†D 217 – 27 T. Tent. Method of Test for Penetration of Greases and Petro latum.

D 91 – 30 T. Tent. Method of Test for Precipitation Number of Lubricating Oils.

*D 94 – 28. Method of Test for Saponification Number.

D 36 – 26. *Method of Test for Softening Point of Bituminous Materials (Ring-and-Ball Method).*

D 71 – 27. *Method of Test for Specific Gravity of Asphalts and Tar Pitches Sufficiently Solid to be Handled in Fragments.*

D 70 – 27. *Method of Test for Specific Gravity of Road Oils, Road Tars, Asphalt Cements and Soft Tar Pitches.*

*D 157 – 28. Method of Test for Steam Emulsion of Lubricating Oils.

D 90 – 30 T. Tent. Method of Test for Sulfur in Motor Fuels, Naphthas and Illuminating Oils (Lamp Method).

*D 129 – 27. Method of Test for Sulfur in Petroleum Oils Heavier than Illuminating Oil.

*D 240 – 27. Method of Test for Thermal Value of Fuel Oil.

D 323 – 30 T. Tent. Method of Test for Determination of Vapor Pressure of Natural Gasoline (Reid Method).

D 88 – 30. Methods of Test for Viscosity of Petroleum Products and Lubricants.

D 95 – 30. Method of Test for Water in Petroleum Products and Other Bituminous Materials.

D 96 – 30. Method of Test for Water and Sediment in Petroleum Products by Means of Centrifuge.

DEFINITIONS

D 288 – 28 T. Tent. Def. of Terms Relating to Petroleum.

ROAD MATERIALS

SPECIFICATIONS

†D 57 – 20. Spec. for Materials for Cement Grout Filler for Brick and Stone Block Pavements.

D 58 – 24. Spec. for Materials for Cement Mortar Bed for Brick, Stone Block, Wood Block, Asphalt Block and Other Block Pavements.

C 7 – 30. *Spec. for Paving Brick.*

* Approved as "American Standard" by the American Standards Association.
† Approved as "American Tentative Standard" by the American Standards Association.

D 59 – 26. Spec. for Block for Granite Block Pavements.
D 131 – 23. Spec. for Block for Recut Granite Block Pavements.
D 132 – 23. Spec. for Block for Durax Granite Pavements.
D 52 – 20. Spec. for Wooden Paving Blocks for Exposed Pavements.
D 63 – 23 T. Tent. Spec. for Commercial Sizes of Broken Stone and Broken Slag for Highway Construction.
D 64 – 20 T. Tent. Spec. for Commercial Sizes of Sand and Gravel for Highway Construction.
D 309 – 30. Spec. for Gravel for Bituminous Concrete Base.
D 190 – 29 T. Tent. Spec. for Broken Stone for Waterbound Base.
D 191 – 29. Spec. for Broken Stone for Waterbound Macadam Surface Course.
D 192 – 29. Spec. for Broken Stone for Bituminous Macadam.
D 193 – 29 T. Tent. Spec. for Broken Stone for Bituminous Concrete Base.
D 194 – 29. Spec. for Broken Stone for Bituminous Concrete Surface.
D 65 – 23. Spec. for Broken Slag for Waterbound Base and Wearing Course.
D 66 – 23. Spec. for Shovel-Run or Crusher-Run Broken Slag for Waterbound Base.
D 195 – 27. Spec. for Broken Slag for Bituminous Macadam Base.
D 196 – 27. Spec. for Broken Slag for Bituminous Concrete Base.
D 159 – 27. Spec. for Broken Slag for Bituminous Macadam Wearing Course.
D 160 – 27. Spec. for Broken Slag for Bituminous Concrete (Coarse-Graded Aggregate Type).
D 161 – 27. Spec. for Broken Slag for Bituminous Concrete (Fine-Graded Aggregate Type).
D 162 – 29. Spec. for Sand for Sheet Asphalt and Bituminous Concrete Pavements.
D 98 – 30 T. Tent. Spec. for Calcium Chloride for Dust Prevention.
D 133 – 23 T. Tent. Spec. for Asphalt Cement, 10 to 15 Penetration, for the Manufacture of Asphalt Block.
D 134 – 23 T. Tent. Spec. for Asphalt Cement, 15 to 25 Penetration, for the Manufacture of Asphalt Block.
D 163 – 23 T. Tent. Spec. for Asphalt Cement, 25 to 30 Penetration, for Use in Sheet Asphalt and Asphaltic-Concrete Pavements.
D 164 – 23 T. Tent. Spec. for Asphalt Cement, 30 to 40 Penetration, for Use in Sheet Asphalt and Asphaltic-Concrete Pavements.
D 99 – 26 T. Tent. Spec. for Asphalt Cement, 40 to 50 Penetration, for Use in Sheet Asphalt and Asphaltic-Concrete Pavements and as Filler for Brick and Block Pavements.
D 100 – 26 T. Tent. Spec. for Asphalt Cement, 50 to 60 Penetration, for Use in Sheet Asphalt and Asphaltic-Concrete Pavements and as Filler for Block Pavements.
D 101 – 26 T. Tent. Spec. for Asphalt Cement, 60 to 70 Penetration, for Use in Sheet Asphalt, Asphaltic Concrete, and Asphalt-Macadam Pavements and as Filler for Block Pavements.
D 102 – 24 T. Tent. Spec. for Asphalt Cement, 85 to 100 Penetration, for Use in Asphalt-Macadam Pavements.
D 103 – 24 T. Tent. Spec. for Asphalt Cement, 100 to 120 Penetration, for Use in Asphalt-Macadam Pavements.

D 135 – 23 T. Tent. Spec. for Asphalt Cement, 120 to 150 Penetration, for Use in Asphalt-Macadam Pavements.
D 104 – 30. Spec. for High-Carbon Tar for Surface Treatment, Cold Application.
D 105 – 30. Spec. for Low-Carbon Tar for Surface Treatment, Cold Application.
D 106 – 28 T. Tent. Spec. for High-Carbon Tar Cement for Use Cold in Repair Work (Cut-Back Product).
D 107 – 28 T. Tent. Spec. for Low-Carbon Tar Cement for Use Cold in Repair Work (Cut-Back Product).
D 108 – 30. Spec. for High-Carbon Tar for Surface Treatment, Hot Application.
D 109 – 30. Spec. for Low-Carbon Tar for Surface Treatment, Hot Application.
D 110 – 30. Spec. for High-Carbon Tar Cement.
D 111 – 30. Spec. for Low-Carbon Tar Cement.
D 112 – 30. Spec. for Coal-Tar Pitch for Stone Block Filler.
D 241 – 26 T. Tent. Spec. for Asphalt Filler for Brick Pavements (Blown Type).
D 242 – 26 T. Tent. Spec. for Mineral Filler for Sheet Asphalt and Bituminous Concrete Pavements.
E 11 – 26. *Spec. for Sieves for Testing Purposes.*

METHODS

D 2 – 26. Method of Test for Abrasion of Rock.
D 289 – 28 T. Tent. Method of Test for Abrasion of Gravel.
*D 3 – 18. Method of Test for Toughness of Rock.
†D 30 – 18. Method of Test for Apparent Specific Gravity of Coarse Aggregates.
D 55 – 25. Methods of Test for Apparent Specific Gravity of Sand, Stone and Slag Screenings, and Other Fine Non-Bituminous Highway Materials.
D 136 – 28. Method of Decantation Test for Sand and Other Fine Aggregates.
D 72 – 21. Method of Test for Quantity of Clay and Silt in Gravel for Highway Construction.
D 220 – 29. Method of Test for the Determination of Moisture Equivalent of Subgrade Soils in the Field.
D 138 – 26 T. Tent. Method of Test for Consistency of Portland-Cement Concrete.
*D 75 – 22. Methods of Sampling Stone, Slag, Gravel, Sand and Stone Block for Use as Highway Materials, Including Some Material Survey Methods.
D 7 – 27. Method of Mechanical Analysis of Sand or Other Fine Highway Material, Except Fine Aggregates Used in Cement Concrete.
D 18 – 16. Method of Mechanical Analysis of Broken Stone or Broken Slag, Except Aggregates Used in Cement Concrete.

* Approved as "American Standard" by the American Standards Association.
† Approved as "American Tentative Standard" by the American Standards Association.

D 19 - 16. Method of Mechanical Analysis of Mixtures of Sand or Other Fine Material with Broken Stone or Broken Slag, Except Aggregates Used in Cement Concrete.
D 35 - 18. Form of Spec. for Certain Commercial Grades of Broken Stone.
*D 4 - 27. Method of Test for the Determination of Bitumen.
D 165 - 27. Method of Test for the Determination of Proportion of Bitumen Soluble in Carbon Tetrachloride.
D 6 - 30. Method of Test for Loss on Heating of Oil and Asphaltic Compounds.
D 20 - 30. Method of Test for Distillation of Bituminous Materials Suitable for Road Treatment.
*D 5 - 25. Method of Test for Penetration of Bituminous Materials.
D 36 - 26. Method of Test for Softening Point of Bituminous Materials (Ring-and-Ball Method).
D 61 - 24. Method of Test for Softening Point of Tar Products (Cube-in-Water Method).
*D 139 - 27. Method of Float Test for Bituminous Materials.
D 70 - 27. Method of Test for Specific Gravity of Road Oils, Road Tars, Asphalt Cements and Soft Tar Pitches.
D 71 - 27. Method of Test for Specific Gravity of Asphalts and Tar Pitches Sufficiently Solid to be Handled in Fragments.
D 113 - 26 T. Tent. Method of Test for Ductility of Bituminous Materials.
D 243 - 28 T. Tent. Method of Test for Residue of Specified Penetration.
D 140 - 25. Methods of Sampling Bituminous Materials.
D 95 - 28. *Method of Test for Water in Petroleum Products and Other Bituminous Materials.*
D 244 - 28 T. Tent. Methods of Testing Bituminous Emulsions.

RECOMMENDED PRACTICE

D 290 - 28 T. Tent. Recommended Practice for Bituminous Paving Plant Inspection.

DEFINITIONS

D 8 - 18. Def. of Terms Relating to Materials for Roads and Pavements.
C 58 - 28. *Def. of the Term Sand.*
C 58 - 28 T. *Tent. Def. of the Term Aggregate.*[1]
E 12 - 27. *Def. of Terms Relating to Specific Gravity.*
E 13 - 28 T. *Tent. Def. of the Term Screen (Sieve).*

COAL AND COKE

SPECIFICATIONS

D 166 - 24. Spec. for Gas and Coking Coals.
D 17 - 16. Spec. for Foundry Coke.

METHODS

†D 21 - 16. Method of Sampling Coal.
*D 271 - 30. Methods of Laboratory Sampling and Analysis of Coal and Coke.

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* Approved as "American Standard" by the American Standards Association.
† Approved as "American Tentative Standard" by the American Standards Association.
[1] To be added, when adopted, to the present Standard Definition of the Term Sand (A.S.T.M. Designation: C 58 - 28).

D 197 – 30. Method of Test for Fineness of Powdered Coal.
D 310 – 29 T. Tent. Method of Test for Size of Anthracite.
D 311 – 30. Method of Test for Sieve Analysis of Crushed Bituminous Coal.
D 291 – 29. Method of Test for Cubic Foot Weight of Crushed Bituminous Coal.
D 292 – 29. Method of Test for Cubic Foot Weight of Coke.
D 141 – 23. Method of Shatter Test for Coke.
D 167 – 24. Method of Test for Volume of Cell Space of Lump Coke.
D 293 – 29. Method of Test for Sieve Analysis of Coke.
D 294 – 29. Method of Tumbler Test for Coke.

DEFINITIONS

D 121 – 30. Def. of Terms Relating to Coal and Coke.
D 121 – 30 T. Tent. Def. of the Term Coke.[1]

TIMBER AND TIMBER PRESERVATIVES

SPECIFICATIONS

D 245 – 30. Spec. for Structural Wood Joist and Planks, Beams and Stringers, and Posts and Timbers.
D 25 – 30 T. Tent. Spec. for Timber Piles.
D 52 – 20. Spec. for Wooden Paving Blocks for Exposed Pavements.

METHODS

*D 143 – 27. Methods of Testing Small Clear Specimens of Timber.
*D 198 – 27. Methods for Conducting Static Tests of Timber in Structural Sizes.
D 38 – 30. Methods of Sampling and Analysis of Creosote Oil.
D 38 – 30 T. Tent. Method for the Determination of the Specific Gravity, 38°/15.5° C., of Creosote Fractions.[2]
D 168 – 30. Method of Test for Coke Residue of Creosote Oil.
D 246 – 30. Method of Test for Distillation of Creosote Oil.
D 199 – 27. Methods of Chemical Analysis of Zinc Chloride.

DEFINITIONS

D 9 – 30. Def. of Terms Relating to Timber.
D 324 – 30 T. Tent. Def. of Terms Relating to Timber Preservatives.

SHIPPING CONTAINERS

SPECIFICATIONS

D 44 – 20 T. Tent. Spec. for Wooden Boxes, Nailed and Lock-Corner Construction, for the Shipment of Canned Foods.
D 45 – 17 T. Tent. Spec. for Canned Foods Boxes, Wirebound Construction.

* Approved as "American Standard" by the American Standards Association.

[1] To be added, when adopted, to the present Standard Definitions of Terms Relating to Coal and Coke (A.S.T.M. Designation: D 121 – 30).

[2] To be added, when adopted, to the present Standard Methods of Sampling and Analysis of Creosote Oil (A.S.T.M. Designation: D 38 – 30).

D 68 – 22 T. Tent. Spec. for Wooden Boxes, Nailed and Lock-Corner Construction.
D 118 – 21 T. Tent. Spec. for 4-One Boxes and Similar Type Boxes.

WATERPROOFING AND ROOFING MATERIALS

SPECIFICATIONS

D 40 – 25. Spec. for Asphalt for Use in Damp-proofing and Waterproofing Below Ground Level.
D 144 – 25. Spec. for Asphalt for Use in Damp-proofing and Waterproofing Above Ground Level.
D 312 – 29 T. Tent. Spec. for Asphalt for Use in Constructing Built-Up Roof Coverings.
D 41 – 26. Spec. for Primer for Use with Asphalt in Damp-proofing and Waterproofing Below and Above Ground Level.
D 42 – 25. Spec. for High-Carbon Coal-Tar Pitch for Use in Damp-proofing and Waterproofing Below Ground Level.
D 145 – 25. Spec. for High-Carbon Coal-Tar Pitch for Use in Damp-proofing and Waterproofing Above Ground Level.
D 200 – 25. Spec. for High-Bitumen Coal-Tar Pitch for Use in Damp-proofing and Waterproofing Below Ground Level.
D 201 – 25. Spec. for High-Bitumen Coal-Tar Pitch for Use in Damp-proofing and Waterproofing Above Ground Level.
D 251 – 27. Spec. for High-Carbon Coal-Tar Pitch for Use in Constructing Built-Up Roofs Surfaced with Slag or Gravel.
D 252 – 27. Spec. for High-Bitumen Coal-Tar Pitch for Use in Constructing Built-Up Roofs Surfaced with Slag or Gravel.
D 43 – 25. Spec. for Creosote Oil for Priming Coat with Coal-Tar Pitch in Damp-proofing and Waterproofing Below and Above Ground Level.
D 169 – 25. Spec. for Asphalt Mastic for Use in Waterproofing.
D 223 – 30. Spec. for Acid Resisting Asphalt Mastic.
D 170 – 25. Spec. for Bituminous Grout for Use in Waterproofing Above Ground Level.
D 171 – 25. Spec. for Bituminous Grout for Use in Waterproofing Below Ground Level.
D 173 – 27. Spec. for Woven Cotton Fabrics Saturated with Bituminous Substances for Use in Waterproofing.
D 174 – 25. Spec. for Burlap Saturated with Bituminous Substances for Use in Waterproofing.
D 224 – 27. Spec. for Asphalt Roll-Roofing Surfaced with Powdered Talc.
D 248 – 27. Spec. for Asphalt Roll-Roofing Surfaced with Granular Talc.
D 225 – 29. Spec. for Asphalt Roll-Roofing and Asphalt Shingles Surfaced with Mineral Granules.
D 249 – 27. Spec. for Heavy Weight Asphalt Roll-Roofing and Heavy Weight Asphalt Shingles Surfaced with Mineral Granules.
D 226 – 27. Spec. for Asphalt-Saturated Roofing Felt for Use in Waterproofing and in Constructing Built-Up Roofs.
D 227 – 27. Spec. for Coal-Tar Saturated Roofing Felt for Use in Waterproofing and in Constructing Built-Up Roofs.
D 250 – 27. Spec. for Asphalt-Saturated Asbestos Felt for Use in Constructing Built-Up Roofs.

METHODS

D 147 - 27. Methods of Testing Bituminous Mastics, Grouts and Like Mixtures.

D 255 - 28. Method of Test for Steam Distillation of Bituminous Protective Coatings.

D 313 - 29 T. Tent. Method of Test for Coarse Particles in Bituminous Materials by Means of Elutriation.

D 146 - 27. Methods of Testing Felted and Woven Fabrics Saturated with Bituminous Substances for Use in Waterproofing and Roofing.

D 228 - 30 T. Tent. Methods of Testing Asphalt Roll-Roofing Surfaced with Fine Talc, Granular Talc, or Mineral Granules, Likewise Asphalt Shingles Surfaced with Mineral Granules.

D 272 - 29 T. Tent. Methods of Analysis of Roofing Felt for Fiber Composition.

SLATE AND BUILDING STONE

METHODS

D 221 - 27 T. Tent. Method of Test for Water Absorption of Slate.

D 222 - 27 T. Tent. Methods of Flexure Testing of Slate. (Determination of Modulus of Rupture and Modulus of Elasticity).

D 273 - 27 T. Tent. Methods of Test for Determining the Insulating Qualities of Slate.

D 326 - 30 T. Tent. Methods of Compression Testing of Natural Building Stone.

D 327 - 30 T. Tent. Methods of Flexure Testing of Natural Building Stone.

D 328 - 30 T. Tent. Methods of Test for Absorption and Apparent Specific Gravity of Natural Building Stone.

DEFINITION

D 247 - 27. Def. of the Term Slate.

INSULATING MATERIALS

SPECIFICATIONS

D 120 - 23. Spec. for Rubber Gloves for Electrical Workers on Apparatus or Circuits not Exceeding 3000 Volts to Ground.

D 178 - 24. Spec. for Rubber Matting for Use Around Electrical Apparatus or Circuits not Exceeding 3000 Volts to Ground.

D 69 - 28. Spec. for Friction Tape for General Use for Electrical Purposes.

D 119 - 28 T. Tent. Spec. for Rubber Insulating Tape.

D 27 - 28 T. Tent. Spec. for Insulated Wire and Cable: 30-per-cent Hevea Rubber.

D 259 - 27. Spec. for Tolerances and Test Methods for Electrical Silk and Cotton Tapes.

D 203 - 25. Spec. for Tolerances and Test Methods for Electrical Cotton Yarns.

D 299 - 29. Spec. for Tolerances and Test Methods for Asbestos Yarns.

D 315 - 29 T. Tent Spec. for Asbestos Tape for Electrical Purposes.

METHODS

D 48 – 30. Methods of Testing Molded Insulating Materials.
D 117 – 27. Methods of Testing Electrical Insulating Oils.
D 115 – 30 T. Tent. Methods of Testing Insulating Varnishes.
D 116 – 30. Methods of Testing Electrical Porcelain.
D 149 – 30 T. Tent. Method of Testing Sheet and Tape Insulating Materials for Dielectric Strength.
D 295 – 29 T. Tent. Methods of Testing Varnished Cloths and Varnished Cloth Tapes.
D 150 – 27 T. Tent. Method of Testing Electrical Insulating Materials for Power Factor and Dielectric Constant at Frequencies of 100 to 1500 Kilocycles.
D 176 – 29 T. Tent. Method of Testing Cable Splicing and Pothead Compounds.
D 202 – 30 T. Tent. Methods of Testing Untreated Insulating Paper.
D 229 – 30 T. Tent. Methods of Testing Laminated Sheet Insulating Materials.
D 256 – 28 T. Tent. Methods of Testing Insulating Materials for Resistance to Impact.
D 257 – 29 T. Tent. Methods of Test for Resistivity of Insulating Materials.
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†D 296 – 28 T. Tent. Spec. for Cotton Rubber-Lined Fire Hose for Public and Private Fire Department Use.
D 46 – 24. Spec. for Wrapped Air Hose for Use with Pneumatic Tools.
D 60 – 24. Spec. for Braided Air Hose for Use with Pneumatic Tools.
D 177 – 24. Spec. for Wrapped Cold Water Hose.
D 54 – 24 T. Tent. Spec. for Steam Hose.
D 120 – 23. Spec. for Rubber Gloves for Electrical Workers on Apparatus or Circuits Not Exceeding 3000 Volts to Ground.
D 178 – 24. Spec. for Rubber Matting for Use Around Electrical Apparatus or Circuits Not Exceeding 3000 Volts to Ground.
D 27 – 28 T. Tent. Spec. for Insulated Wire and Cable: 30-per-cent Hevea Rubber.
D 151 – 23. Spec. for Rubber Pump Valves.
D 69 – 28. Spec. for Friction Tape for General Use for Electrical Purposes.
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D 15 – 24. Methods of Testing Rubber Products.
D 297 – 29 T. Tent. Methods of Chemical Analysis of Rubber Products.[1]
D 314 – 29 T. Tent. Method of Test for Hardness of Soft Rubber (In Slab Form).

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† Approved as "American Tentative Standard" by the American Standards Association.

[1] To supersede, when adopted, the Chemical Tests appearing in the present Standard Methods of Testing Rubber Products (A.S.T.M. Designation: D 15 – 24).

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[1] To be added, when adopted, to the present Standard Definitions of Terms Relating to Textile Materials (A.S.T.M. Designation: D 123 – 30).

D 184 – 25. Spec. for A.S.T.M. Partial-Immersion Thermometer for General Use, −5 to +400° C., +20 to +760° F.
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E 10 – 27. Methods of Brinell Hardness Testing of Metallic Materials.

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[1] To be added, when adopted, to the present Standard Definitions of Terms Relating to Methods of Testing (A.S.T.M. Designation: E 6 – 30).

PRICE LIST OF PUBLICATIONS

(September 2, 1930)

BOOK OF A.S.T.M. STANDARDS

The Book of A.S.T.M. Standards is published triennially, and contains all of the standards of the Society in their latest revised form. The 1930 edition, two parts (about 2300 pp.), issued in cloth and half-leather bindings, contains the 427 standards adopted by the Society up to 1930. Copies, including the subsequent receipt of supplements issued in the intervening years, may be obtained at the following prices:

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	Both Parts	9.00	12.00

BOOK OF A.S.T.M. TENTATIVE STANDARDS

Tentative standards are proposed standards that are published for one or more years to elicit criticism before their formal adoption as standard by the Society. Although still in the trial stage of A.S.T.M. procedure, they represent the latest thought of the committees on the subjects covered and therefore are finding important applications in the various industries. The Book of A.S.T.M. Tentative Standards is published annually and contains all of the tentative standards of the Society in their latest revised form. The 1930 edition (about 750 pp.) contains 155 tentative standards and may be obtained at the following prices:

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A Bibliography on Effect of Temperature on the Properties of Metals prepared by the Joint Research Committee of the A.S.M.E. and A.S.T.M. on the Effect of Temperature on the Properties of Metals has been issued as an A.S.M.E. research publication by the American Society of Mechanical Engineers. The bibliography is indexed chronologically (1825–1928) and by authors, and contains a subject index as well.

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Separate reprints have been made available of the Reports of Committee A-5 on Corrosion of Iron and Steel for the years 1923 to 1930, inclusive, containing the results of annual inspection of the atmospheric corrosion tests on copper-bearing and non-copper-bearing sheets, the total immersion tests on similar material and the reports of the more recent years on an extensive investigation on atmospheric exposure tests of galvanized material.

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Reprints are available of the 1930 Report of Committee D-2 on Petroleum Products and Lubricants, together with 33 standards and 14 tentative methods of test and one tentative definition of terms relating to petroleum and petroleum products (283 pp.). This pamphlet is published for the purpose of presenting under a single cover as a means of ready reference the standard procedures for the more important tests.

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A pamphlet is available entitled "Report on the Significance of Tests of Petroleum Products," compiled by Committee D-2 on Petroleum Products and Lubricants, constituting a discussion of the various methods of test applicable to petroleum products. The report was prepared to meet the growing demand for information regarding the significance of the tests used in evaluating petroleum products.

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Reprints are available of the 1930 Report of Committee D-9 on Electrical Insulating Materials, together with 9 standard and 12 tentative specifications and methods of test relating to electrical insulating materials (192 pp.). This pamphlet is published for the purpose of presenting under a single cover as a means of ready reference the standard procedures for the more important tests, together with the specifications for electrical insulating materials.

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A special reprint pamphlet is available containing all of the standard and tentative specifications and methods of test of the Society relating to textile materials (122 pp.). In addition to the 15 standards and 8 tentative standards the pamphlet contains data relative thereto and information concerning Committee D-13 on Textile Materials.

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ORDERS

Orders for publications should be addressed to:

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1315 Spruce Street,
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NOTICE

Special attention is called to the blank letter of recommendation for membership in the Society, and the application blanks for membership bound in the back of this book. It is hoped that members will put these blanks to good use as occasion offers.

AMERICAN SOCIETY

FOR

TESTING MATERIALS

ORGANIZED IN 1898
INCORPORATED IN 1902

S&IS1

A.S.T.M. STANDARDS

(ISSUED TRIENNIALLY)

1927

PART I. METALS

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FOREWORD

The 1927 Book of Standards is published in two parts, Part I covering Metals and Part II covering Non-Metallic Materials. In these two Parts appear the 340 standard specifications, methods of test, definitions of terms and recommended practices in effect at the time of publication. A complete list of these standards is given on page 822.

This volume comprises Part I and contains 147 standards, of which 144 are standards relating specifically to metals and 3 are standards of a general nature applying to both metals and non-metals, which latter standards for convenience are included in both Parts.

The Book of Standards is issued triennially. Those standards which are adopted by the Society in the intervening years are published in supplements to the Book of Standards. In accordance with this policy there will be issued a Supplementary Pamphlet of A.S.T.M. Standards Adopted in 1928 and a second Supplementary Pamphlet of A.S.T.M. Standards Adopted in 1929, which will contain the standards approved by the Society in those years. The next edition of the Book of Standards will be published in 1930.

Before a standard receives the formal approval of the Society it is published for one or more years as a tentative standard. The tentative standards submitted or revised in any given year appear in the Proceedings of the Society for that year. In addition all tentative standards in effect in any given year are published collectively in a Book of A.S.T.M. Tentative Standards which is issued each year about October 15. Criticisms of such tentative standards are solicited, of which the standing committee responsible for the preparation and revision of the standards in question takes due cognizance before recommending final adoption as standard by the Society. The procedure for the submission and adoption of standards is given in the Regulations Governing Standing Committees appearing on pages 814 to 821, inclusive. A list of the current tentative standards is printed in this volume on pages 837 to 846. Corresponding lists of tentative standards effective in subsequent years will appear in the supplements to the Book of Standards for those years.

GUIDE TO THE USE

OF THE

BOOK OF STANDARDS

The standards in this Book are assembled in a sequence determined by the specific materials or products to which they apply. For convenience in using the Book of Standards each Part is provided with **two Tables of Contents,** one a listing of the standards in the order in which they appear in the volume grouped according to the subjects to which they relate, the other a listing of the standards **in numeric sequence** of their serial designations.

In addition to the Tables of Contents a complete **Subject Index** appears in the back of each Part. (For the Index to this Part, see page 847.) Each standard has been indexed under the principal subjects covered by the standard. The principal words in each item of the index have been printed in bold face type to facilitate finding the item desired. This index should be the most convenient means of locating any standard appearing in the volume, especially if only the general subject matter covered is known.

As mentioned in the Foreword, a complete **list of all standards and tentative standards** of the Society in effect as of September 1, 1927, is included in this volume, pages 822 to 846. Corresponding lists of standards and tentative standards in effect as of September 1, 1928, and September 1, 1929, respectively, will appear in the supplements to the Book of Standards for those years.

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The standards are grouped according to the materials to which they apply. Duplicate listings appear in italics.

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* Approved as "Tentative American Standard" by the American Engineering Standards Committee.

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STANDARD SPECIFICATIONS
FOR
OPEN-HEARTH CARBON-STEEL RAILS[1]

Serial Designation: A 1 – 27

These specifications are issued under the fixed designation A 1; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ADOPTED, 1907; REVISED, 1907, 1908, 1909, 1914, 1921, 1924, 1927.

MANUFACTURE

Mill Practices.

1. (*a*) The entire process of manufacture shall be in accordance with the best current state of the art. It is expected that thoroughly deoxidized dead setting steel will be furnished and that in every stage of manufacture strict adherence to the standards of best practice of the individual mill will be observed.

(*b*) Should anything occur in the process of manufacture, which, in the judgment of the inspector, varies detrimentally from regular care and practice, the inspector will immediately notify the chief inspector and the general superintendent of the mill, confirming such report in writing. If after full investigation, the inspector is not satisfied as to the good quality of the rails in question, and the rail, complying in other respects to these specifications, be loaded for shipment, the inspector will immediately forward a copy of this report to the purchaser.

Discard.

2. Sufficient discard shall be taken from the ingot to insure freedom from injurious segregation and pipe.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

3. The steel shall conform to the following requirements as to chemical composition:

	Weight, lb. per yd.				
Elements Considered	50–69	70–84	85–100	101–120	121–140
Carbon, per cent....	0.50 – 0.63	0.53 – 0.70	0.62 – 0.77	0.67 – 0.83	0.72 – 0.89
Manganese, per cent.	0.60 – 0.90	0.60 – 0.90	0.60 – 0.90	0.50 – 0.90	0.50 – 0.90
Phosphorus, maximum per cent....	0.04	0.04	0.04	0.04	0.04
Silicon, minimum per cent.....	0.15	0.15	0.15	0.15	0.15

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

Average Carbon.

4. (*a*) In any rolling, it is desired that the number of heats above the mean carbon percentage of the specific range shall be at least equal to the number of heats below the mean, and that the average carbon shall be as high as the mean.

(*b*) For information only, the manufacturer shall furnish the carbon and manganese analysis on drillings taken from both the "O" and "M" positions of the head at the top end of the "A" rail of the last full ingot rolled on each tenth heat.

Ladle Analyses.

5. Separate analyses shall be made from drillings taken from test ingots representing the second and one of the last full ingots of the heat to determine the percentages of carbon and manganese. The percentages of phosphorus, sulfur, and silicon shall be determined on equally mixed drillings from the test ingots. The average analysis of the ladle test ingots shall conform to the chemical requirements. A portion of the drillings shall be furnished to the inspector upon request for check analysis.

PHYSICAL PROPERTIES AND TESTS

Physical Requirements.

6. (*a*) Ductility and resistance to impact will be determined by the standard A.R.E.A. drop testing machine, with test specimens from 4 ft. to 6 ft. long cut from the top of the "A" rails from the second, middle and last full ingots of each heat. These specimens shall be marked on the base with gage marks 1 in. apart for 3 in. each side of the center of the test specimens for measuring the ductility of the metal. The distance between supports shall be 3 ft. for sections under 106 lb. For sections 106 lb. and over it shall be 4 ft.

(*b*) The temperature of the test specimens shall not exceed 38° C. (100° F.)

Height of Drop.

7. The test specimens shall be placed head upwards on the supports and subjected to one blow from the tup falling free from the following heights:

Weight of Rail, lb. per yd.	Height of Drop, ft.
50– 60, inclusive	16
61– 80, inclusive	17
81– 90, inclusive	18
91–100, inclusive	19
101–120, inclusive	20
121–140, inclusive	22

Drop Test Requirements.

8. (*a*) If all three of the specimens endure the above tests without fracture, all the rails of the melt will be accepted subject to final inspection for surface, section and finish.

(*b*) If one of the three specimens fails, all the "A" rails of the

heat will be rejected. Specimens shall then be cut from the bottom end of the same "A" rails or the top end of the "B" rails and tested.

(*c*) If any of these test specimens fail, the "B" rails of the heat will be rejected. Three additional specimens shall then be taken from the bottom end of the "B" rails or the top end of the "C" rails. If all these test specimens endure the test, the balance of the heat will be accepted. If any of these test specimens fails, the entire heat shall be rejected.

Elongation and Permanent Set.

9. (*a*) One of the three test specimens shall be given a sufficient number of blows to determine, for information only, the exhausted ductility, reported inch by inch over the entire 6 in. gaged. No ductility readings will be taken between blows. The other two specimens shall be nicked and broken. The fracture of each specimen shall be examined to determine if the fracture conforms to the requirements of Section 10.

(*b*) For information only, the permanent set measured by middle ordinate in inches in a length of 3 ft. shall be recorded after the first blow on all test specimens.

(*c*) For information only, one of the three test specimens shall be tested by Brinell indentation upon the head of the rail, and the diameter of the indentation shall be entered on the test record. The ball shall be 19 mm. in diameter and the pressure 100,000 lb.

Interior Condition.

10. If the fracture on any test specimen exhibits seams, laminations, cavities, interposed foreign matter, or a distinctly bright or fine-grained structure, all top rails represented shall be classified as "X-Rayls."

STANDARD SECTION, LENGTH AND WEIGHT

Lengths.

11. The standard length of rails shall be 39 ft. or 33 ft., as ordered, when measured at a temperature of 15.5° C. (60° F.). When the length specified is 39 ft., 11 per cent of the entire order will be accepted in shorter lengths varying by 1 ft. from 38 ft. to 25 ft., and a variation of $\frac{3}{8}$ in. from the specified length will be allowed, except that on 15 per cent of the order a variation of $\frac{7}{16}$ in. will be allowed.

When the specified length is 33 ft., 10 per cent of the entire order will be accepted in shorter lengths varying by 1 ft. from 32 ft. to 25 ft., and a variation of $\frac{1}{4}$ in. from the specified length will be allowed, except that on 15 per cent of the order a variation of $\frac{3}{8}$ in. will be allowed.

Section.

12. The section of the rails shall conform as accurately as possible to the templets furnished by the purchaser. A variation of $\frac{1}{64}$ in.

less or $\frac{1}{32}$ in. greater than the specified height will be permitted. A variation of $\frac{1}{16}$ in. in the length of either flange will be permitted, but the variation in total width of base must not exceed $\frac{1}{16}$ in. No variation will be allowed in dimensions affecting the fit of the joint bars, except that the fishing templet approved by the purchaser may stand out not to exceed $\frac{1}{16}$ in. laterally.

Weight. 13. A variation of 0.5 per cent from the calculated weight of section as applied to the entire order will be allowed.

WORKMANSHIP AND FINISH

Drilling. 14. Circular holes for joint bolts shall be drilled to conform to the drawings and dimensions furnished by the purchaser. A variation of $\frac{1}{32}$ in. in the size and location of bolt holes will be allowed.

Finishing. 15. (*a*) All rails shall be smooth on the heads, straight in line and without twists, waves or kinks. The supports for rails in the straightening presses shall have flat surfaces and be free from hollow places, bends or crooks, and shall be spaced not less than 60 in. When placed head up on a horizontal surface, rails that are slightly higher at the ends than the middle will be accepted, provided they contain a uniform sweep, the middle ordinate of which does not exceed $1\frac{1}{4}$ in. in 39 ft. They shall be sawed square at the ends, a variation of not more than $\frac{1}{32}$ in. being allowed, and burrs shall be entirely removed.

(*b*) Rails presented for inspection which do not conform to the requirements of Section 14 or Paragraph (*c*) may be re-conditioned by the mill, provided they can be made to fully meet the requirements.

(*c*) When any finished rail shows conditions as described in Section 10 at either end or at any drilled hole, it shall be cut back to sound metal, and accepted as an "X-Rayl."

CLASSIFICATION OF RAILS

No. 1 Rails. 16. No. 1 rails shall be free from injurious defects and flaws of all kinds.

X-Rayls. 17. X-Rayls are rails as described in Sections 10 and 15 (*c*).

No. 2 Rails. 18. Rails which conform to the following requirements will be accepted as No. 2 Rails:

(*a*) Rails which do not contain surface imperfections in such number or of such character as will in the judgment of the inspector render them unfit for recognized uses.

(*b*) Rails of A.R.A. type of sections arriving at the straightening presses with sharp kinks or greater camber than that indicated by a middle ordinate of 6 in. in 39 ft. or 4 in. in 33 ft. Rails of A.S.C.E. type of sections arriving at the straightening presses with

sharp kinks or greater camber than that indicated by a middle ordinate of 7 in. in 39 ft. or 5 in. in 33 ft.

MARKING

19. Brands made so plain and sharp that they may be read as long as the rails are in service shall be rolled on or hot stamped into the side of the web of each rail in accordance with the following requirements and to indicate: **Marking.**

(*a*) Name of the manufacturer, the month and year of manufacture, and the weight and type of section of rail as rolled.

(*b*) The heat number and the ingot number as rolled shall be stamped in the web of each rail where it will not be covered by the joint bars.

(*c*) The top rails shall normally be lettered "A" and the succeeding ones "B", "C", "D", "E", etc., consecutively, but in case the top discard is greater than normal, the rail lettering shall conform to the amount of discard, the top rail becoming "B" or other succeeding letter to suit the condition.

Only the "A," "B" and "C" rails are required to be lettered when the normal weight per yard is less than 70 lb.

(*d*) All rails shall be branded "O. H." in addition to other marks.

20. (*a*) Rails accepted as No. 2 rails shall have the ends painted white and shall be stamped with the figure 2 on both end faces. **Classification Markings.**

(*b*) Rails accepted as "X-Rayls" shall have the ends painted brown and shall be stamped with the letter "X" on both end faces.

(*c*) "A" rails shall have both ends painted yellow.

(*d*) No. 1 rails less than 39 ft. long shall have both ends painted green.

(*e*) All rails of heats the carbon content of which exceeds the mean carbon percentage of the specific range shall have both ends painted blue.

Individual rails shall be painted only one color, according to the order of precedence listed above.

LOADING

21. Rails shall be carefully handled in such manner as to avoid injury and shall be loaded as follows: **Loading.**

(*a*) No. 1 low-carbon rails shall be loaded in separate cars.

(*b*) No. 1 high-carbon rails shall be loaded in separate cars.

(*c*) No. 2 rails shall be loaded in separate cars.

(*d*) "X-Rayls" shall be loaded in separate cars.

(*e*) No. 1 "A" rails shall be loaded in separate cars.

(*f*) No. 1 short rails shall be loaded in separate cars. No subdivision by classification markings other than listed above is necessary for separate loading.

INSPECTION AND REJECTION

Inspection.

22. Inspection and tests shall be made at the works of the manufacturer before shipment, and the works management shall afford all reasonable facilities for determining the satisfactory quality of the rails accepted.

Acceptance and Payment.

23. (*a*) In order to be accepted, the rails offered shall fulfill all the requirements of these specifications.

(*b*) No. 2 rails to the extent of 8 per cent of the whole order will be accepted.

(*c*) Rails accepted will be paid for according to actual weights.

STANDARD SPECIFICATIONS
FOR
THE MANUFACTURE OF OPEN-HEARTH STEEL GIRDER RAILS OF PLAIN, GROOVED AND GUARD TYPES[1]

Serial Designation: A 2 – 27

These specifications are issued under the fixed designation A 2; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ADOPTED, 1912; REVISED, 1921, 1924, 1927.

1. (*a*) These specifications are intended to cover the manufacture of open-hearth steel girder rails of plain, grooved and guard types of the classes specified. **Scope.**

(*b*) Girder-guard rails shall be Class A.

(*c*) Plain and grooved-girder rails under 135 lb. per yd. in weight shall be specified as either Class A or Class B.

(*d*) Plain and grooved-girder rails of 135 lb. per yd. in weight and heavier shall be Class C, unless otherwise specified.

MANUFACTURE

2. The steel shall be made by the open-hearth process. The entire process of manufacture and testing shall be in accordance with the best current practice. **Process.**

3. Bled ingots and ingots or blooms which show the effects of injurious treatment shall not be used. **Bled Ingots.**

4. A sufficient discard from the top of each ingot shall be made at any stage of the manufacture to obtain sound rails. When finished rails show piping, they may be cut to shorter lengths until all evidence of this is removed. **Discard.**

CHEMICAL PROPERTIES AND TESTS

5. The steel shall conform to the following requirements as to chemical compositions, according to the class specified in the order: **Chemical Composition.**

[1]Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

These specifications agree with those of the American Electric Railway Engineering Association and the American Electric Railway Association and were prepared jointly by these organizations and the American Society for Testing Materials.

	CLASS A	CLASS B	CLASS C
Carbon, per cent....	0.60 – 0.75	0.70 – 0.85	0.75 – 0.90
Manganese, per cent.	0.60 – 0.90	0.60 – 0.90	0.60 – 0.90
Silicon, per cent.....	0.15 – 0.40	0.15 – 0.40	0.15 – 0.40
Phosphorus, per cent.	not over 0.04	not over 0.04	not over 0.04

Ladle Analyses.

6. To determine whether the material conforms to the requirements specified in Section 5, an analysis shall be made by the manufacturer from a test ingot taken during the pouring of each melt. Drillings for analysis shall be taken not less than $\frac{1}{8}$ in. beneath the surface of the test ingot. A copy of this analysis shall be given to the purchaser or his representative.

Check Analyses.

7. A check analysis may be made as information from time to time by the purchaser from a test ingot or drillings therefrom furnished by the manufacturer.

PHYSICAL PROPERTIES AND TESTS

Impression Test Specimens.

8. (*a*) Four representative sections of rail from each melt shall be selected by the inspector as test specimens.

(*b*) Excess scale on the head or web of the sections shall be carefully removed.

Impression Test.

9. (*a*) The head of each specimen shall be subjected to a pressure of 100,000 lb. (45,359 kg.) for a period of 15 seconds, applied through a hardened steel ball 0.75 in. (19.05 mm.) in diameter.

(*b*) *Test Balls.*—The steel test ball shall have a minimum Brinell hardness of 600 and it shall not be possible to attack the surface of the ball with an American Swiss Pillar File No. 2.

(*c*) *Permissible Variation in Test Balls.*—When fractured, the ball shall show a fine uniform grain, and the fracture shall resist file attack for at least one-third of its depth from the surface of the ball. The permissible variation in the diameter of the ball shall not be greater than 0.002 in. over or under the standard size, and the permanent deformation under the required loading shall not be greater than 0.003 in.

(*d*) *Depth of Impressions.*—The average depth of impression obtained on the four specimens shall not be more than 0.1496 in. (3.8 mm.) for Class A rails, 0.1391 in. (3.5 mm.) for Class B rails, and 0.1338 in. (3.4 mm.) for Class C rails.

Retests.

10. If the average of the impression tests on the head of the section from any melt fails to conform to the requirements specified in Section 9 (*d*) the manufacturer may at his option test each rail from such melt by making an impression test on the web, as described in Section 9 (*a*). Rails so retested which conform to the requirements as to depths of impression specified in Section 9 (*d*) shall be accepted.

STANDARD SECTIONS, LENGTHS, AND WEIGHTS

Section. 11. (*a*) The cold template of the manufacturer shall conform to the specified section as shown in detail on the drawing of the purchaser and shall at all times be maintained perfect.

(*b*) The section of the rail shall conform as accurately as possible to the template, and within the following permissible variations:

(1) The height shall not vary more than $\frac{1}{64}$ in. under nor more than $\frac{1}{32}$ in. over that specified.

(2) The overall width of head and tram shall not vary more than $\frac{1}{8}$ in. from that specified. Any variation which would affect the gage line more than $\frac{1}{32}$ in. will not be allowed.

(3) The overall width of base shall not vary more than $\frac{1}{8}$ in. under that specified for widths less than $6\frac{1}{2}$ in., $\frac{3}{16}$ in. under for a width of $6\frac{1}{2}$ in., and $\frac{1}{4}$ in. under for a width of 7 in.

(4) Any variation which would affect the fit of the splice bars will not be allowed.

(5) The base of the rail shall be at right angles to the web; and the convexity shall not exceed $\frac{1}{32}$ in.

(*c*) When necessary on account of the type of track construction, and notice to that effect has been given to the manufacturer, special care shall be taken to maintain the proper position of the gage line with respect to the outer edge of the base.

Length. 12. (*a*) Unless otherwise specified, the lengths of rails at a temperature of 60° F. (15.5° C.) shall be 60 and 62 ft. for those sections in which the weight per yard will permit; except girder-guard rails which shall be 30 and 32 ft., unless otherwise specified.

(*b*) The lengths shall not vary more than $\frac{1}{4}$ in. from those specified.

(*c*) Shorter lengths, varying by one foot down to 40 ft. for plain and grooved-girder rails and 24 ft. for girder-guard rails, will be accepted to the extent of 10 per cent by weight of each class on the order.

Weight. 13. (*a*) The weight of the rails per yard as specified in the order shall be maintained as nearly as possible after conforming to the requirements specified in Section 11.

(*b*) The total weight of an order shall not vary more than 0.5 per cent from that specified.

(*c*) Payments shall be based on actual weights.

WORKMANSHIP AND FINISH

Straightening. 14. (*a*) Rails on the hot beds shall be protected from water or snow and shall be carefully handled to minimize cold-straightening.

(*b*) The distance between the rail supports in the cold-straightening presses shall not be less than 42 in., except as may be necessary

near the ends of the rails. The gag shall have rounded corners to avoid injury to the rails.

(*c*) Rails heard to snap or check while being straightened shall be at once rejected.

Finish. 15. (*a*) Rails shall be smooth on the head, straight in line and surface without any twists, waves, or kinks, particular attention being given to having the ends without kinks or droop.

(*b*) All burrs or flow caused by drilling or sawing shall be carefully removed.

(*c*) Rails shall be free from gag marks and other injurious defects of cold-straightening.

(*d*) Any rails to be cold-straightened showing sharp kinks or greater camber than that indicated by the middle ordinate of 18 in. in 60 ft. shall be classed as No. 2 rails.

DRILLING, MILLING AND PUNCHING

Drilling. 16. Circular holes for splice bar bolts, bonds and tie rods shall be drilled to conform to the drawings and dimensions furnished by the purchaser and within the following permissible variations:

(*a*) The diameter of bolt holes shall not vary more than $\frac{1}{32}$ in. over or under that specified. The diameter of bond holes shall not be over the size specified, but may be $\frac{1}{32}$ in. under. The diameter of the tie rod holes shall not be less than that specified but may be $\frac{1}{16}$ in. over.

(*b*) The location of bolt and bond holes shall not vary more than $\frac{1}{16}$ in. either longitudinally or vertically from that specified. The location of the tie rod holes shall not vary more than $\frac{1}{4}$ in. vertically and not more than $\frac{1}{2}$ in. longitudinally from that specified.

(*c*) Bond holes shall be truly cylindrical and not conical.

Milling. 17. The ends of the rail shall be milled. The plane of the finished end surface shall, in the direction of the width of the rail, be at right angles to the gage with a permissible variation of $\frac{1}{32}$ in. in 6 in. and, in the direction of the height of the rail, be inclined to the plane of the base so that the top edge of the head will project beyond the bottom edge of the base not less than $\frac{1}{32}$ in. nor more than $\frac{3}{32}$ in.

Punching. 18. Unless otherwise specified by the purchaser, the tie rod holes in Class A rails may be punched, and, when so made, they shall be free from burrs, fins, etc. Punched tie-rod holes shall not be less in diameter than specified, but may be $\frac{1}{8}$ in. over size.

CLASSIFICATION OF RAILS

No. 1 Rails. 19. Rails which are free from injurious defects and flaws of all kinds shall be classed as No. 1 rails.

20. (*a*) Rails which are rough on the head or which by reason of surface or other imperfections are not classed as No. 1 rails, shall be classed as No. 2 rails; provided they do not, in the judgment of the inspector, contain imperfections in such number and of such character as to render them unfit for No. 2 rail uses, and provided they conform to the requirements specified in Section 11. **No. 2 Rails.**

(*b*) No. 2 rails will be accepted to the extent of 10 per cent by weight of the entire order.

MARKING AND LOADING

21. (*a*) The name or brand of the manufacturer, the year and month of manufacture, the letters "O.H.," the weight of the rail, and the section number, shall be legibly rolled in raised letters and figures on the web. The melt number shall be legibly stamped on each rail where it will not be covered subsequently by the splice bars. **Marking.**

(*b*) Both ends of all short-length No. 1 rails shall be painted green. Both ends of all No. 2 rails shall be painted white and shall have two heavy center-punch marks on the web at each end at such a distance from the end that they will not be covered subsequently by the splice bars.

22. (*a*) Rails shall be loaded in the presence of the inspector, and shall be handled in such a manner as not to bruise the flanges or cause other injuries. **Loading.**

(*b*) Rails of each class shall be placed together in loadings.

(*c*) Rails shall be paired as to length before shipment.

INSPECTION

23. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment, and shall be so conducted as not to interfere unnecessarily with the operation of the works. **Inspection.**

STANDARD SPECIFICATIONS
FOR
LOW-CARBON-STEEL SPLICE BARS[1]

Serial Designation: A 3 – 24

These specifications are issued under the fixed designation A 3; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ADOPTED, 1901; REVISED, 1909, 1912, 1913, 1914, 1924.

MANUFACTURE

Process.

1. The steel shall be made by either or both the following processes: bessemer or open-hearth.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

2. The steel shall conform to the following requirements as to chemical composition:

Phosphorus	Bessemer	not over 0.10 per cent
	Open-hearth	" " 0.05 "

Ladle Analyses.

3. (*a*) A carbon determination shall be made of each melt of bessemer steel, and two analyses every 24 hours representing the average of the elements carbon, manganese, phosphorus and sulfur contained in the steel, one for each 12-hour period, respectively. These analyses shall be made from drillings taken at least $\frac{1}{8}$ in. beneath the surface of a test ingot obtained during the pouring of the melts. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 2.

(*b*) An analysis of each melt of open-hearth steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus and sulfur. This analysis shall be made from drillings taken at least $\frac{1}{8}$ in. beneath the surface of a test ingot obtained during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 2.

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

Check Analyses.

4. An analysis may be made by the purchaser from a finished splice bar representing each melt. The phosphorus content thus determined shall not exceed that specified in Section 2 by more than 25 per cent.

PHYSICAL PROPERTIES AND TESTS

Tension Tests.

5. The splice bars shall conform to the following requirements as to tensile properties:

Tensile strength, lb. per sq. in.....	55 000 – 65 000
Elongation in 8 in., min., per cent.....	25

Bend Tests.

6. The test specimen shall bend cold through 180 deg. flat on itself without cracking on the outside of the bent portion.

Test Specimens.

7. Tension and bend test specimens shall be taken from the finished rolled bars. Tension test specimens shall be of 8-in. gage length. Bend tests may be made of an unpunched splice bar, flattened if necessary.

Number of Tests.

8. (*a*) One tension and one bend test shall be made from each melt.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 5 and any part of the fracture is outside the middle third of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

WORKMANSHIP AND FINISH

Workmanship.

9. (*a*) The splice bars shall be smoothly rolled, true to template, and shall accurately fit the rails for which they are intended. The bars shall be sheared to length, and the punching and notching shall conform to the dimensions specified by the purchaser. A variation of $\frac{1}{32}$ in. from the specified size and location of holes, and of $\frac{1}{8}$ in. from the specified length of splice bar, will be permitted. Any variation from a straight line in a vertical plane shall be such as will make the bars high in the center. The maximum camber in either plane shall not exceed $\frac{1}{16}$ in. in 24 in., except as specified in Paragraph (*b*).

(*b*) For splice bars for girder and high tee rails, any variation from a straight line in a vertical plane shall be such as will make the bars high in the center, and the maximum camber in this plane shall not exceed $\frac{3}{64}$ in. in 24 in. Any variation from a straight line in a horizontal plane shall be such as will

make the bars convex toward the web of the rail, and the maximum camber in this plane shall not exceed $\frac{1}{16}$ in. in 24 in.

Finish. 10. The finished splice bars shall be free from injurious defects and shall have a workmanlike finish.

MARKING

Marking. 11. The name or brand of the manufacturer and the year of manufacture shall be rolled in raised letters and figures on the side of the rolled bars, and a portion of this marking shall appear on each finished splice bar.

INSPECTION AND REJECTION

Inspection. 12. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the splice bars ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the splice bars are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection. 3. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 4 shall be reported within five working days from the receipt of samples.

(*b*) Splice bars which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

Rehearing. 14. Samples tested in accordance with Section 4, which represent rejected splice bars, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

STANDARD SPECIFICATIONS
FOR
MEDIUM-CARBON-STEEL SPLICE BARS[1]

Serial Designation: A 4 – 14

These specifications are issued under the fixed designation A 4; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ADOPTED, 1913; REVISED, 1914.

MANUFACTURE

1. The steel shall be made by the open-hearth process. **Process.**

2. (*a*) The splice bars may be punched, slotted, and, in the case of special designs, shaped either hot or cold. **Finishing.**

(*b*) Bars that are punched, slotted or shaped cold shall be subsequently annealed.

CHEMICAL PROPERTIES AND TESTS

3. The steel shall conform to the following requirements as to chemical composition: **Chemical Composition.**

Carbon	not under 0.30 per cent
Phosphorus	not over 0.04 "

4. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus and sulfur. This analysis shall be made from drillings taken at least $\frac{1}{8}$ in. beneath the surface of a test ingot obtained during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 3. **Ladle Analyses.**

5. An analysis may be made by the purchaser from a finished splice bar representing each melt. The phosphorus content thus determined shall not exceed that specified in Section 3 by more than 25 per cent. **Check Analyses.**

PHYSICAL PROPERTIES AND TESTS

6. The splice bars shall conform to the following minimum requirements as to tensile properties: **Tension Tests.**

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

Tensile strength, lb. per sq. in.	68 000
Elongation in 2 in., per cent.	$\frac{1\,600\,000}{\text{Tens. str.}}$

but in no case under 20 per cent.

Bend Tests. 7. The bend test specimen specified in Section 8 shall bend cold through 180 deg. around a pin the diameter of which is equal to twice the thickness of the specimen, without cracking on the outside of the bent portion.

Test Specimens. 8. Tension and bend test specimens shall be taken from the finished bars. Tension test specimens shall conform to the dimensions shown in Fig. 1. The ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial. Bend test specimens may be $\frac{1}{2}$ in. square in section, or rectangular in section with two parallel faces as rolled.

Optional Bend Tests. 9. If preferred by the manufacturer and approved by the purchaser, the following bend test may be substituted for that

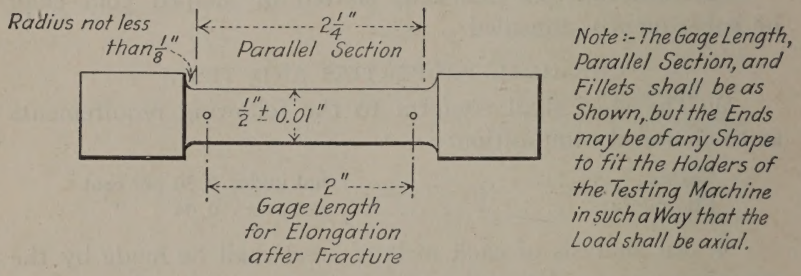

Radius not less than 1/8"
2 1/4"
Parallel Section
1/2" ± 0.01"
2"
Gage Length for Elongation after Fracture
Note:-The Gage Length, Parallel Section, and Fillets shall be as Shown, but the Ends may be of any Shape to fit the Holders of the Testing Machine in such a Way that the Load shall be axial.

FIG. 1.

described in Section 7: A piece of the finished bar shall bend cold through 90 deg. around a pin the diameter of which is equal to twice the greatest thickness of the section, without cracking on the outside of the bent portion.

Number of Tests. 10. (*a*) One tension and one bend test shall be made from each melt.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 6 and any part of the fracture is more than $\frac{3}{4}$ in. from the center of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

WORKMANSHIP AND FINISH

Workmanship.

11. (*a*) The splice bars shall be smoothly rolled, true to template, and shall accurately fit the rails for which they are intended. The bars shall be sheared to length, and the punching and notching shall conform to the dimensions specified by the purchaser. A variation of $\frac{1}{32}$ in. from the specified size of holes, of $\frac{1}{16}$ in. from the specified location of holes, and of $\frac{1}{8}$ in. from the specified length of splice bar, will be permitted. Any variation from a straight line in a vertical plane shall be such as will make the bars high in the center. The maximum camber in either plane shall not exceed $\frac{1}{16}$ in. in 24 in., except as specified in Paragraph (*b*).

(*b*) For splice bars for girder and high tee rails, any variation from a straight line in a vertical plane shall be such as will make the bars high in the center, and the maximum camber in this plane shall not exceed $\frac{3}{64}$ in. in 24 in. Any variation from a straight line in a horizontal plane shall be such as will make the bars convex toward the web of the rail, and the maximum camber in this plane shall not exceed $\frac{1}{16}$ in. in 24 in.

Finish.

12. The finished splice bars shall be free from injurious defects and shall have a workmanlike finish.

MARKING

Marking.

13. The name or brand of the manufacturer and the year of manufacture shall be rolled in raised letters and figures on the side of the rolled bars, and a portion of this marking shall appear on each finished splice bar.

INSPECTION AND REJECTION

Inspection.

14. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the splice bars ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the splice bars are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection.

15. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 5 shall be reported within five working days from the receipt of samples.

(*b*) Splice bars which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

Rehearing.

16. Samples tested in accordance with Section 5, which represent rejected splice bars, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

STANDARD SPECIFICATIONS FOR HIGH-CARBON-STEEL SPLICE BARS[1]

Serial Designation: A 5 – 14

These specifications are issued under the fixed designation A 5; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ADOPTED, 1913; REVISED, 1914.

MANUFACTURE

Process.

1. The steel shall be made by the open-hearth process.

Finishing.

2. The splice bars shall be punched, slotted and, in the case of special designs, shaped at a temperature not less than 750° C.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

3. The steel shall conform to the following requirements as to chemical composition:

Carbon	not under 0.45 per cent
Phosphorus	not over 0.04 "

Ladle Analyses.

4. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus and sulfur. This analysis shall be made from drillings taken at least ⅛ in. beneath the surface of a test ingot obtained during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 3.

Check Analyses.

5. An analysis may be made by the purchaser from a finished splice bar representing each melt. The phosphorus content thus determined shall not exceed that specified in Section 3 by more than 25 per cent.

PHYSICAL PROPERTIES AND TESTS

Tension Tests.

6. The splice bars shall conform to the following minimum requirements as to tensile properties:

Tensile strength, lb. per sq. in	85,000
Elongation in 2 in., per cent	14

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

Bend Tests.

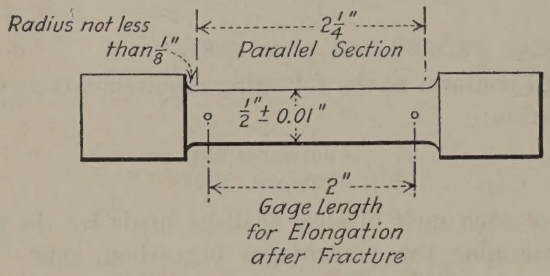
7. The bend test specimen specified in Section 8 shall bend cold through 90 deg. around a pin the diameter of which is equal to three times the thickness of the specimen, without cracking on the outside of the bent portion.

Test Specimens.

8. Tension and bend test specimens shall be taken from the finished bars. Tension test specimens shall conform to the dimensions shown in Fig. 1. The ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial. Bend test specimens may be $\frac{1}{2}$ in. square in section, or rectangular in section with two parallel faces as rolled.

Optional Bend Tests.

9. If preferred by the manufacturer and approved by the purchaser, the following bend test may be substituted for that described in Section 7: A piece of the finished bar shall bend cold through 45 deg. around a pin the diameter of which is equal to three times the greatest thickness of the section, without cracking on the outside of the bent portion.



Note:-The Gage Length, Parallel Section, and Fillets shall be as Shown, but the Ends may be of any Shape to fit the Holders of the Testing Machine in such a Way that the Load shall be axial.

FIG. 1

Number of Tests.

10. (*a*) One tension and one bend test shall be made from each melt.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 6 and any part of the fracture is more than $\frac{3}{4}$ in. from the center of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

WORKMANSHIP AND FINISH

Workmanship.

11. (*a*) The splice bars shall be smoothly rolled, true to template, and shall accurately fit the rails for which they are intended. The bars shall be sheared to length, and the punching

and notching shall conform to the dimensions specified by the purchaser. A variation of $\frac{1}{32}$ in. from the specified size of holes, of $\frac{1}{16}$ in. from the specified location of holes, and of $\frac{1}{8}$ in. from the specified length of splice bar, will be permitted. Any variation from a straight line in a vertical plane shall be such as will make the bars high in the center. The maximum camber in either plane shall not exceed $\frac{1}{16}$ in. in 24 in., except as specified in Paragraph (*b*).

(*b*) For splice bars for girder and high tee rails, any variation from a straight line in a vertical plane shall be such as will make the bars high in the center, and the maximum camber in this plane shall not exceed $\frac{3}{64}$ in. in 24 in. Any variation from a straight line in a horizontal plane shall be such as will make the bars convex toward the web of the rail, and the maximum camber in this plane shall not exceed $\frac{1}{16}$ in. in 24 in.

12. The finished splice bars shall be free from injurious defects and shall have a workmanlike finish. Finish.

MARKING

13. The name or brand of the manufacturer and the year of manufacture shall be rolled in raised letters and figures on the side of the rolled bars, and a portion of this marking shall appear on each finished splice bar. Marking.

INSPECTION AND REJECTION

14. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the splice bars ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the splice bars are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works. Inspection.

15. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 5 shall be reported within five working days from the receipt of samples. Rejection.

(*b*) Splice bars which show injurious defects subsequent to their acceptance at the maunfacturer's works will be rejected, and the manufacturer shall be notified.

Rehearing.

16. Samples tested in accordance with Section 5, which represent rejected splice bars, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

STANDARD SPECIFICATIONS
FOR
EXTRA-HIGH-CARBON-STEEL SPLICE BARS[1]

Serial Designation: A 6 – 14

These specifications are issued under the fixed designation A 6; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ADOPTED, 1913; REVISED, 1914.

MANUFACTURE

1. The steel shall be made by the open-hearth process. **Process.**

2. The splice bars shall be punched, slotted, sheared and, in the case of special designs, shaped at a temperature not less than 750° C.; except that bars may be cold-sawed to length. **Finishing.**

CHEMICAL PROPERTIES AND TESTS

3. The steel shall conform to the following requirement as to chemical composition: **Chemical Composition.**

Phosphorus	not over 0.04 per cent

4. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus and sulfur. This analysis shall be made from drillings taken at least $\frac{1}{8}$ in. beneath the surface of a test ingot obtained during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirement specified in Section 3. **Ladle Analyses.**

5. An analysis may be made by the purchaser from a finished splice bar representing each melt. The phosphorus content thus determined shall not exceed that specified in Section 3 by more than 25 per cent. **Check Analyses.**

PHYSICAL PROPERTIES AND TESTS

6. The splice bars shall conform to the following minimum requirements as to tensile properties: **Tension Tests.**

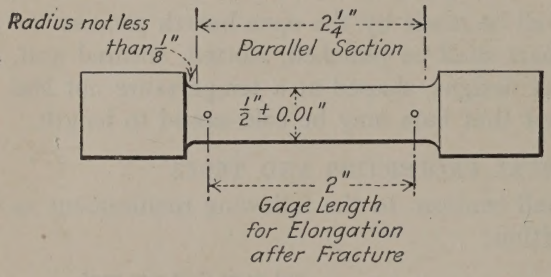
Tensile strength, lb. per sq. in.	100 000
Elongation in 2 in., per cent	10

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

Bend Tests. 7. The bend test specimen specified in Section 8 shall bend cold through 60 deg. around a pin the diameter of which is equal to three times the thickness of the specimen, without cracking on the outside of the bent portion.

Test Specimens. 8. Tension and bend test specimens shall be taken from the finished bars. Tension test specimens shall conform to the dimensions shown in Fig. 1. The ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial. Bend test specimens may be $\frac{1}{2}$ in. square in section, or rectangular in section with two parallel faces as rolled.

Optional Bend Tests. 9. If preferred by the manufacturer and approved by the purchaser, the following bend test may be substituted for that



Note:-The Gage Length, Parallel Section, and Fillets shall be as Shown, but the Ends may be of any Shape to fit the Holders of the Testing Machine in such a Way that the Load shall be axial.

FIG. 1.

described in Section 7: A piece of the finished bar shall bend cold through 30 deg. around a pin the diameter of which is equal to three times the greatest thickness of the section, without cracking on the outside of the bent portion.

Number of Tests. 10. (*a*) One tension and one bend test shall be made from each melt.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 6 and any part of the fracture is more than $\frac{3}{4}$ in. from the center of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

WORKMANSHIP AND FINISH

Workmanship. 11. (*a*) The splice bars shall be smoothly rolled, true to template, and shall accurately fit the rails for which they are

intended. The bars shall be sheared to length, and the punching and notching shall conform to the dimensions specified by the purchaser. A variation of $\frac{1}{32}$ in. from the specified size of holes, of $\frac{1}{16}$ in. from the specified location of holes, and of $\frac{1}{8}$ in. from the specified length of splice bar, will be permitted. Any variation from a straight line in a vertical plane shall be such as will make the bars high in the center. The maximum camber in either plane shall not exceed $\frac{1}{16}$ in. in 24 in., except as specified in Paragraph (*b*).

(*b*) For splice bars for girder and high tee rails, any variation from a straight line in a vertical plane shall be such as will make the bars high in the center, and the maximum camber in this plane shall not exceed $\frac{3}{64}$ in. in 24 in. Any variation from a straight line in a horizontal plane shall be such as will make the bars convex toward the web of the rail, and the maximum camber in this plane shall not exceed $\frac{1}{16}$ in. in 24 in.

Finish.

12. The finished splice bars shall be free from injurious defects and shall have a workmanlike finish.

MARKING

Marking.

13. The name or brand of the manufacturer and the year of manufacture shall be rolled in raised letters and figures on the side of the rolled bars, and a portion of this marking shall appear on each finished splice bar.

INSPECTION AND REJECTION

Inspection.

14. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the splice bars ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the splice bars are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection.

15. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 5 shall be reported within five working days from the receipt of samples.

(*b*) Splice bars which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

Rehearing.

16. Samples tested in accordance with Section 5, which represent rejected splice bars, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

STANDARD SPECIFICATIONS
FOR
QUENCHED HIGH-CARBON-STEEL SPLICE BARS[1]

Serial Designation: A 49–21

These specifications are issued under the fixed designation A 49; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ADOPTED, 1915; REVISED, 1921.

MANUFACTURE

1. The steel shall be made by the open-hearth process. **Process.**

2. The splice bars shall be punched, slotted and, in the case of special designs, shaped at a temperature not less than 750° C., and subsequently quenched. **Finishing and Heat Treatment.**

CHEMICAL PROPERTIES AND TESTS

3. The steel shall conform to the following requirements as to chemical composition: **Chemical Composition.**

Carbon	not over 0.60 per cent
Manganese	" " 0.80 "
Phosphorus	" " 0.04 "

4. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus and sulfur. This analysis shall be made from drillings taken at least $\frac{1}{8}$ in. beneath the surface of a test ingot obtained during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 3. **Ladle Analyses.**

5. An analysis may be made by the purchaser from a finished splice bar representing each melt. The phosphorus content thus determined shall not exceed that specified in Section 3 by more than 25 per cent. **Check Analyses.**

PHYSICAL PROPERTIES AND TESTS

6. (*a*) The splice bars shall conform to the following minimum requirements as to tensile properties: **Tension Tests.**

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

Tensile strength, lb. per sq. in	100 000
Yield point, " "	65 000
Elongation in 2 in., per cent	10

(*b*) The yield point shall be determined by the drop of the beam of the testing machine.

Bend Tests. 7. The bend test specimen specified in Section 8 shall bend cold through 90 deg. around a pin the diameter of which is equal to three times the thickness of the specimen, without cracking on the outside of the bent portion.

Test Specimens. 8. Tension and bend test specimens shall be taken from the finished bars. Tension test specimens shall conform to the dimensions shown in Fig. 1. The ends shall be of a form to fit the holders of the testing machine in such a way that the load

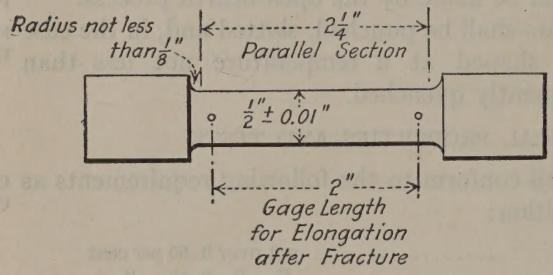

Radius not less than 1/8"
2 1/4"
Parallel Section
1/2" ± 0.01"
2"
Gage Length for Elongation after Fracture
Note:-The Gage Length, Parallel Section, and Fillets shall be as Shown, but the Ends may be of any Shape to fit the Holders of the Testing Machine in such a Way that the Load shall be axial.

FIG. 1.

shall be axial. Bend test specimens may be $\frac{1}{2}$ in. square in section, or rectangular in section with two parallel faces as rolled, with corners rounded to a radius not over $\frac{1}{16}$ in.

Optional Bend Tests. 9. If preferred by the manufacturer and approved by the purchaser, the following bend test may be substituted for that described in Section 7: A piece of the finished bar shall bend cold through 45 deg. around a pin the diameter of which is equal to three times the greatest thickness of the section, without cracking on the outside of the bent portion.

Number of Tests. 10. (*a*) One tension and one bend test shall be made from each melt.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 6 and any part of the fracture is more than $\frac{3}{4}$ in. from the center of the gage

length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

Retests. 11. If the results of the physical tests of any test lot do not conform to the requirements specified, the manufacturer may re-treat such lot one or more times in which case two additional tension and two additional bend tests shall be made from such lot, all of which shall conform to the requirements specified.

WORKMANSHIP AND FINISH

Workmanship. 12. The splice bars shall be smoothly rolled, true to template, and shall accurately fit the rails for which they are intended. The bars shall be sheared to length, and the punching and notching shall conform to the dimensions specified by the purchaser. A variation of $\frac{1}{32}$ in. from the specified size of holes, of $\frac{1}{16}$ in. from the specified location of holes, and of $\frac{1}{8}$ in. from the specified length of splice bar, will be permitted. Any variation from a straight line in a vertical plane shall be such as will make the bars high in the center. The maximum camber in either plane shall not exceed $\frac{1}{16}$ in. in 24 in.

Finish. 13. The finished splice bars shall be free from injurious defects and shall have a workmanlike finish.

MARKING

Marking. 14. The name or brand of the manufacturer and the year of manufacture shall be rolled in raised letters and figures on the side of the rolled bars, and a portion of this marking shall appear on each finished splice bar.

INSPECTION AND REJECTION

Inspection. 15. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the splice bars ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the splice bars are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection. 16. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 5 shall be reported within five working days from the receipt of samples.

(*b*) Splice bars which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

Rehearing. 17. Samples tested in accordance with Section 5, which represent rejected splice bars, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

STANDARD SPECIFICATIONS
FOR
LOW-CARBON-STEEL TRACK BOLTS[1]

Serial Designation: A 76 – 27

These specifications are issued under the fixed designation A 76; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1918; ADOPTED IN AMENDED FORM, 1927.

MANUFACTURE

Process.

1. (*a*) The steel shall be made by either or both the following processes: bessemer or open-hearth.

(*b*) The threads may be cut or rolled.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

2. (*a*) The steel for the bolts shall conform to the following requirements as to chemical composition:

Phosphorus	Bessemer	not over 0.10 per cent.
	Open-hearth	" " 0.05 "

(*b*) The steel for the nuts shall be "soft steel."

Ladle Analyses.

3. (*a*) A carbon determination shall be made of each melt of Bessemer steel, and two analyses every 24 hours representing the average of the elements carbon, manganese, phosphorus and sulfur, contained in the steel, one for each 12-hour period, respectively. These analyses shall be made from drillings taken at least $\frac{1}{8}$ in. beneath the surface of a test ingot obtained during the pouring of the melts. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 2.

(*b*) An analysis of each melt of open-hearth steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus and sulfur. This analysis shall be made from drillings taken at least $\frac{1}{8}$ in. beneath the surface of a test ingot obtained during the pouring of the melt. The chem-

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

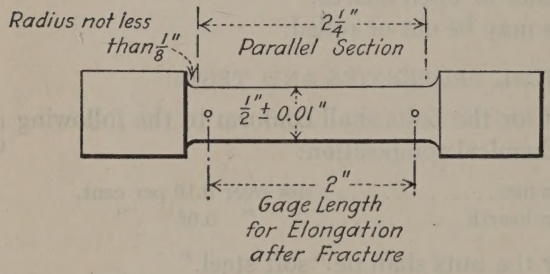
ical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 2.

Check Analyses. 4. An analysis may be made by the purchaser from a finished bolt representing each melt. The phosphorus content thus determined shall not exceed that specified in Section 2 by more than 25 per cent.

PHYSICAL PROPERTIES AND TESTS

Tension Tests. 5. The stock from which the bolts are made shall conform to the following requirements as to tensile properties:

Tensile strength, lb. per sq. in	55 000 – 70 000
Elongation in 8 in., min., per cent	$\frac{1\,500\,000}{\text{Tens. str.}}$
Elongation in 2 in., min., per cent	22



Note:-The Gage Length, Parallel Section, and Fillets shall be as Shown, but the Ends may be of any Shape to fit the Holders of the Testing Machine in such a Way that the Load shall be axial.

FIG. 1

Bend Tests. 6. The test specimen shall bend cold through 180 deg. flat on itself without cracking on the outside of the bent portion.

Test Specimens. 7. Tension and bend test specimens shall be taken from a finished bolt or from the full-size rolled bars. Tension-test specimens shall be of 8-in. gage length when taken from the rolled bars. When taken from a finished bolt the tension-test specimen shall conform to the dimensions shown in Fig. 1.

Number of Tests. 8. (*a*) One tension and one bend test shall be made from each melt of steel. When the melts can not be identified, one tension and one bend test shall be made from each lot of 10 tons or fraction thereof.

(*b*) If any test specimen develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension-test specimen is less than that specified in Section 5 and any part of

the fracture is outside the middle third of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

Retests.

9. If the results of the physical tests of any test lot do not conform to the requirements specified, two additional tension and two additional bend tests shall be made from such lot, all of which shall conform to the requirements specified.

PERMISSIBLE VARIATIONS

Permissible Variations.

10. The bolts and nuts shall conform to the dimensions specified by the purchaser subject to the following variations: A variation of $\frac{1}{32}$ in. under and $\frac{1}{64}$ in. over the specified diameter of the shank of the bolt will be permitted. The diameter of rolled thread shall not exceed the diameter of the shank more than $\frac{1}{16}$ in. for bolts $\frac{7}{8}$ in. in diameter and under, nor more than $\frac{3}{32}$ in. for bolts 1 in. in diameter and over. The outside diameter of the finished rolled threads shall not exceed the diameter of the shank of a cut thread bolt of corresponding size. The length of the bolt under the head shall not vary more than $\frac{1}{8}$ in. from that specified. A variation in the dimensions of the elliptical shoulders under the head of $\frac{1}{32}$ in. and a taper of the shoulder of $\frac{1}{32}$ in. will be permitted.

WORKMANSHIP AND FINISH

Workmanship.

11. The bolts and nuts shall be neatly formed and free from fins or nicking. The head of the bolt shall be concentric with and firmly joined to the shank, with the under side at right angles to the axis of the bolt. The threads shall be sharp and true to gage and of the design specified by the purchaser. The nuts shall have a hand free fit on the bolt from two to six turns, and wrench tight the balance of the screw length without distorting the threads or twisting the shank. They shall be screwed on the bolts before packing, a sufficient number of turns to hold them in place until used.

Finish.

12. The finished bolts and nuts shall be free from injurious defects and shall have a workmanlike finish.

MARKING

Marking.

13. (*a*) A letter or brand indicating the manufacturer shall be pressed on the head of the bolt when it is formed.

(*b*) Bolts shall be packed in serviceable packages. All packages shall be plainly marked as to material, size of bolts and name of manufacturer.

INSPECTION AND REJECTION

Inspection. 14. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the bolts and nuts ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the bolts and nuts are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection. 15. Bolts and nuts which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

STANDARD SPECIFICATIONS
FOR
QUENCHED CARBON-STEEL TRACK BOLTS[1]

Serial Designation: A 50 - 24

These specifications are issued under the fixed designation A 50; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ADOPTED, 1915; REVISED, 1916, 1921, 1924.

MANUFACTURE

Process

1. (*a*) The steel for the bolts shall be made by the open-hearth process.

(*b*) The steel for the nuts shall be made by either or both the following processes: bessemer or open-hearth.

Finishing and Heat Treatment.

2. The bolts shall enter the quenching medium at a temperature not less than 790° C. The threads may be rolled either hot or cold.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

3. The steel for the bolts shall conform to the following requirements as to chemical composition:

Carbon	not under 0.30 per cent
Phosphorus	not over 0.04 "

Ladle Analyses.

4. (*a*) A carbon determination shall be made of each melt of bessemer steel, and two analyses every 24 hours representing the average of the elements carbon, manganese, phosphorus and sulfur contained in the steel, one for each 12-hour period, respectively. These analyses shall be made from drillings taken at least $\frac{1}{8}$ in. beneath the surface of a test ingot obtained during the pouring of the melts. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 3.

(*b*) An analysis of each melt of open-hearth steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus and sulfur. This analysis shall be made from drillings

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

taken at least $\frac{1}{8}$ in. beneath the surface of a test ingot obtained during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 3.

Check Analyses.

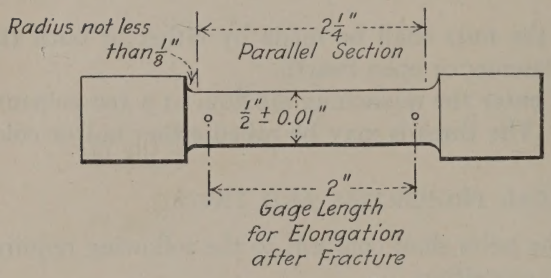
5. An analysis may be made by the purchaser from a finished bolt representing each melt. The phosphorus content thus determined shall not exceed that specified in Section 3 by more than 25 per cent.

PHYSICAL PROPERTIES AND TESTS

Tension Tests.

6. (*a*) The bolts shall conform to the following minimum requirements as to tensile properties:

Tensile strength, lb. per sq. in.	100 000
Yield point, lb. per sq. in.	70 000
Elongation in 2 in., per cent	12



Note:-The Gage Length, Parallel Section, and Fillets shall be as Shown, but the Ends may be of any Shape to fit the Holders of the Testing Machine in such a Way that the Load shall be axial.

FIG. 1.

(*b*) Nuts shall be capable of developing the strength of the finished bolt up to its yield point.

(*c*) The yield point shall be determined by the drop of the beam of the testing machine.

Bend Tests.

7. Full-size bolts shall bend cold through 45 deg. around a pin the diameter of which is equal to the diameter of the bolt, without cracking on the outside of the bent portion.

Test Specimens.

8. Tension test specimens shall be taken from the finished bolts and shall conform to the dimensions shown in Fig. 1. The ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial.

Number of Tests.

9. (*a*) One tension and one bend test shall be made from each lot of 50 kegs or fraction thereof.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 6 (*a*) and any part of the fracture is more than $\frac{3}{4}$ in. from the center of the gage length, as indicated by scribe scratches marked on the specimen before testing, or if the bend test specimen breaks in the threaded portion, a retest shall be allowed.

Retests.

10. If the results of the physical tests of any test lot do not conform to the requirements specified, the manufacturer may re-treat such lot one or more times in which case two additional tension and two additional bend tests shall be made from such lot, all of which shall conform to the requirements specified.

PERMISSIBLE VARIATIONS

Permissible Variations.

11. The bolts and nuts shall conform to the dimensions specified by the purchaser subject to the following variations: A variation of $\frac{1}{32}$ in. under and $\frac{1}{64}$ in. over the specified diameter of the shank of the bolt will be permitted. The diameter of rolled thread shall not exceed the diameter of the shank more than $\frac{1}{16}$ in. for bolts $\frac{7}{8}$ in. in diameter and under, nor more than $\frac{3}{32}$ in. for bolts 1 in. in diameter and over. The outside diameter of the finished rolled threads shall not exceed the diameter of the shank of a cut thread bolt of corresponding size. The length of the bolt under the head shall not vary more than $\frac{1}{8}$ in. from that specified. A variation in the dimensions of the elliptical shoulders under the head of $\frac{1}{32}$ in. and a taper of the shoulder of $\frac{1}{32}$ in. will be permitted.

WORKMANSHIP AND FINISH

Workmanship.

12. The bolts and nuts shall be neatly formed and free from fins or nicking. The head of the bolt shall be concentric with and firmly joined to the shank, with the under side at right angles to the axis of the bolt. The threads shall be sharp and true to gage and of the design specified by the purchaser. The nuts shall have a hand free fit on the bolt from two to six turns, and wrench tight the balance of the screw length without distorting the threads or twisting the shank. They shall be screwed on the bolts before packing, a sufficient number of turns to hold them in place until used.

Finish.

13. The finished bolts and nuts shall be free from injurious defects and shall have a workmanlike finish.

MARKING

Marking.

14. A letter or brand indicating the manufacturer shall be pressed on the head of the bolt while it is being formed.

INSPECTION AND REJECTION

Inspection.

15. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacturer of the bolts and nuts ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the bolts and nuts are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection.

16. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 5 shall be reported within five working days from the receipt of samples.

(*b*) Bolts and nuts which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

Rehearing.

17. Samples tested in accordance with Section 5, which represent rejected bolts and nuts, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

STANDARD SPECIFICATIONS
FOR
QUENCHED ALLOY-STEEL TRACK BOLTS[1]

Serial Designation: A 51 – 21

These specifications are issued under the fixed designation A 51; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ADOPTED, 1915; REVISED, 1916, 1921.

MANUFACTURE

Process.

1. (*a*) The steel for the bolts shall be made by either or both the following processes: open-hearth or electric-furnace.

(*b*) The steel for the nuts shall be made by either or both the following processes: bessemer or open-hearth.

Finishing and Heat Treatment.

2. The bolts shall enter the quenching medium at a temperature of not less than 790° C. The threads may be rolled either hot or cold.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

3. The steel for the bolts shall conform to the following requirement as to chemical composition:

Phosphorus	not over 0.035 per cent.

Ladle Analyses.

4. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus and sulfur, and any other elements used to obtain the physical properties specified in Sections 6 and 7. This analysis shall be made from drillings taken at least $\frac{1}{8}$ in. beneath the surface of a test ingot obtained during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirement specified in Section 3.

Check Analyses.

5. An analysis may be made by the purchaser from a finished bolt representing each melt. The phosphorus content thus determined shall not exceed that specified in Section 3 by more than 25 per cent.

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

PHYSICAL PROPERTIES AND TESTS

Tension Tests.

6. (*a*) The bolts shall conform to the following minimum requirements as to tensile properties:

Tensile strength, lb. per sq. in.	110 000
Yield point, " "	85 000
Elongation in 2 in., per cent	12

(*b*) Nuts shall be capable of developing the full strength of the finished bolt up to its yield point.

(*c*) The yield point shall be determined by the drop of the beam of the testing machine.

Bend Tests.

7. Full-size bolts shall bend cold through 90 deg. around a pin the diameter of which is equal to the diameter of the bolt, without cracking on the outside of the bent portion.

Test Specimens.

8. Tension test specimens shall be taken from the finished bolts and shall conform to the dimensions shown in Fig. 1. The ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial.

Number of Tests.

9. (*a*) One tension and one bend test shall be made from each lot of 50 kegs or fraction thereof.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 6 (*a*) and any part of the fracture is more than $\frac{3}{4}$ in. from the center of the gage length, as indicated by scribe scratches marked on the specimen before testing, or if the bend test specimen breaks in the threaded portion, a retest shall be allowed.

Retests.

10. If the results of the physical tests of any test lot do not conform to the requirements specified, two additional tension and two additional bend tests shall be made from such lot, all of which shall conform to the requirements specified.

PERMISSIBLE VARIATIONS

Permissible Variations.

11. The bolts and nuts shall conform to the dimensions specified by the purchaser subject to the following variations: A variation of $\frac{1}{32}$ in. under and $\frac{1}{64}$ in. over the specified diameter of the shank of the bolt will be permitted. The diameter of rolled thread shall not exceed the diameter of the shank more than $\frac{1}{16}$ in. for bolts $\frac{7}{8}$ in. in diameter and under, nor more than $\frac{3}{32}$ in. for bolts 1 in. in diameter and over. The outside diameter of the finished rolled threads shall not exceed the diameter of the shank of a cut

thread bolt of corresponding size. The length of the bolt under the head shall not vary more than $\frac{1}{8}$ in. from that specified. A variation in the dimensions of the elliptical shoulders under the head of $\frac{1}{32}$ in. and a taper of the shoulder of $\frac{1}{32}$ in. will be permitted.

WORKMANSHIP AND FINISH

Workmanship.

12. The bolts and nuts shall be neatly formed and free from fins or nicking. The head of the bolt shall be concentric with and firmly joined to the shank, with the under side at right angles to the axis of the bolt. The threads shall be sharp and true to gage and of the design specified by the purchaser. The nuts shall have a hand free fit on the bolt from two to six turns, and wrench tight the balance of the screw length without distorting the threads or

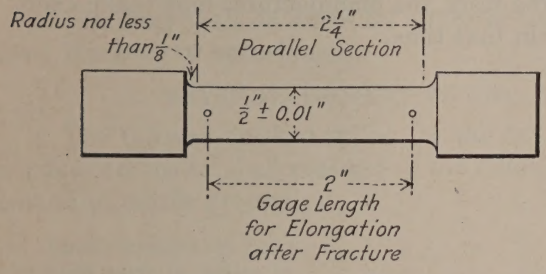

Radius not less than 1/8"
2 1/4"
Parallel Section
1/2" ± 0.01"
2"
Gage Length for Elongation after Fracture
Note:-The Gage Length, Parallel Section, and Fillets shall be as Shown, but the Ends may be of any Shape to fit the Holders of the Testing Machine in such a Way that the Load shall be axial.

FIG. 1.

twisting the shank. They shall be screwed on the bolts before packing, a sufficient number of turns to hold them in place until used.

Finish.

13. The finished bolts and nuts shall be free from injurious defects and shall have a workmanlike finish.

MARKING

Marking.

14. A letter or brand indicating the manufacturer shall be pressed on the head of the bolt while it is being formed.

INSPECTION AND REJECTION

Inspection.

15. The inspector representing the purchaser shall have free entry. at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the bolts and nuts ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the bolts and nuts are being furnished in accordance with these specifications.

All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection.

16. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 5 shall be reported within five working days from the receipt of samples.

(*b*) Bolts and nuts which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

Rehearing.

17. Samples tested in accordance with Section 5, which represent rejected bolts and nuts, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

STANDARD SPECIFICATIONS FOR STEEL TRACK SPIKES[1]

Serial Designation: A 65 – 24

These specifications are issued under the fixed designation A 65; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1916; ADOPTED, 1918, 1924.

MANUFACTURE

Process.

1. The steel shall be made by either or both the following processes: bessemer or open-hearth.

PHYSICAL PROPERTIES AND TESTS

Tension Tests.

2. The full-size finished spikes, or the full-size bars from which the spikes are made, shall conform to the following minimum requirements as to tensile properties:

Tensile strength, lb. per sq. in	55 000
Yield point, lb. per sq. in	0.5 tens. str.
Elongation in 2 in., per cent	25

Bend Tests.

3. (*a*) The body of the full-size finished spikes shall bend cold through 180 deg. flat on itself, without cracking on the outside of the bent portion.

(*b*) The head of the full-size finished spikes shall bend backward to the line of the face of the spike, without cracking on the outside of the bent portion.

Number of Tests.

4. (*a*) One tension and one bend test of each kind shall be made from each lot of 10 tons or fraction thereof.

(*b*) If any test specimen develops flaws, it may be discarded and another specimen substituted.

Retests.

5. If any tension test specimen breaks more than $\frac{3}{4}$ in. from the center of the gage length, a retest shall be allowed.

WORKMANSHIP AND FINISH

Workmanship.

6. The spikes shall conform to the dimensions specified by the purchaser except that a variation of $\frac{1}{32}$ in. over and $\frac{1}{64}$ in. under the

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

specified dimension of the body of the spike, and a variation of $\frac{1}{8}$ in. over and $\frac{1}{16}$ in. under the specified dimension of the head of the spike will be permitted. A variation of $\frac{1}{4}$ in. over and nothing under the specified length of the spike, measured from the under side of the head to the point, will be permitted. A variation of 1 deg. in the specified angle of the under side of the head of the spike will be permitted.

Finish. 7. The finished spikes shall be free from injurious defects and shall have a workmanlike finish.

INSPECTION AND REJECTION

Inspection. 8. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the spikes ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the spikes are being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection. 9. Spikes which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

STANDARD SPECIFICATIONS
FOR
STEEL SCREW SPIKES[1]

Serial Designation: A 66 – 21

These specifications are issued under the fixed designation A 66; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1916; ADOPTED, 1918; REVISED, 1921.

MANUFACTURE

Process. 1. The steel shall be made by either or both the following processes: bessemer or open-hearth.

Finishing. 2. The heads of the spikes shall be formed and the threads rolled at a temperature not less than 750° C.

PHYSICAL PROPERTIES AND TESTS

Tension Tests. 3. The full-size finished spikes shall conform to the following minimum requirements as to tensile properties:

Tensile strength, lb. per sq. in	60 000
Yield point, lb. per sq. in	0.5 tens. str.
Elongation in 2 in., per cent	20

Bend Tests. 4. The full-size finished spikes shall bend cold through 90 deg. around a pin the diameter of which is equal to three times the diameter of the spike, without cracking on the outside of the bent portion.

Number of Tests. 5. (*a*) One tension and one bend test shall be made from each lot of 100 kegs or fraction thereof.

(*b*) If any spike tested develops flaws, it may be discarded and another spike substituted.

Retests. 6. (*a*) If the percentage of elongation of any tension test spike is less than that specified in Section 3, a retest shall be allowed.

(*b*) If any tension test spike breaks more than $\frac{3}{4}$ in. from the center of the gage length, a retest shall be allowed.

WORKMANSHIP AND FINISH

Workmanship. 7. The spikes shall conform to the dimensions specified by the purchaser. The head shall be concentric with, and firmly

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

joined to, the body of the spike. The threads shall be sharp and true to gage and of the design specified by the purchaser. A variation of $\frac{1}{32}$ in. over the specified diameter of the unthreaded portion of the body of the spike will be permitted. A variation of $\frac{1}{32}$ in. over the specified diameter of the threaded portion of the spike will be permitted. A variation of $\frac{1}{16}$ in. under and $\frac{1}{8}$ in. over in the reach of the head of the spike will be permitted. A variation of $\frac{1}{8}$ in. from the specified length of the spike will be permitted.

Finish. 8. The finished spikes shall be free from injurious defects and shall have a workmanlike finish.

MARKING

Marking. 9. A letter or brand indicating the manufacturer shall be pressed on the head of the spike while it is being formed.

INSPECTION AND REJECTION

Inspection. 10. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the spikes ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the spikes are being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection. 11. Spikes which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

STANDARD SPECIFICATIONS
FOR
STRUCTURAL STEEL FOR BRIDGES[1]

Serial Designation: A 7 – 24

These specifications are issued under the fixed designation A 7; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ADOPTED, 1901; REVISED, 1905, 1909, 1913, 1914, 1915, 1916, 1921, 1924.

Steel Castings.

1. The Standard Specifications for Steel Castings (Serial Designation: A 27) of the American Society for Testing Materials,[2] shall govern the purchase of steel castings for bridges. Unless otherwise specified, Class B castings, medium grade, shall be used.

MANUFACTURE

Process.

2. The steel shall be made by the open-hearth process.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

3. The steel shall conform to the following requirements as to chemical composition:

		Structural Steel.	Rivet Steel.
Phosphorus	Acid	not over 0.06 per cent	not over 0.04 per cent
	Basic	" " 0.04 "	" " 0.04 "
Sulfur		" " 0.05 "	" " 0.045 "

Ladle Analyses.

4. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus and sulfur. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 3.

Check Analyses.

5. Analyses may be made by the purchaser from finished material representing each melt. The phosphorus and sulfur content thus determined shall not exceed that specified in Section 3 by more than 25 per cent.

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

[2] See p. 231.

PHYSICAL PROPERTIES AND TESTS

Tension Tests.

6. (*a*) The material shall conform to the following requirements as to tensile properties:

Properties Considered.	Structural Steel.	Rivet Steel.
Tensile strength, lb. per sq. in.	55 000 – 65 000[a]	46 000 – 56 000
Yield point, min., " " but in no case less than	0.5 tens. str. 30 000	0.5 tens. str. 25 000
Elongation in 8 in., min., per cent	$\frac{1\,500\,000[b]}{\text{Tens. str.}}$	$\frac{1\,500\,000}{\text{Tens. str.}}$
Elongation in 2 in., " "	22	.....

[a] See Paragraph (*b*).
[b] See Section 7.

(*b*) In order to meet the required minimum tensile strength of full-size annealed eyebars, the purchaser may determine the tensile strength to be obtained in specimen tests; the range shall not exceed 14,000 lb. per sq. in., and the maximum shall not exceed 74,000 lb. per sq. in. The material shall conform to the requirements as to physical properties other than that of tensile strength, specified in Sections 6, 7 and 8(*b*).

(*c*) The yield point shall be determined by the drop of the beam of the testing machine.

Modification in Elongation.

7. (*a*) For structural steel over $\frac{3}{4}$ in. in thickness or diameter, a deduction from the percentage of elongation in 8 in. specified in Section 6 (*a*) of 0.25 per cent shall be made for each increase of $\frac{1}{32}$ in. of the specified thickness or diameter above $\frac{3}{4}$ in., to a minimum of 18 per cent.

(*b*) For structural steel under $\frac{5}{16}$ in. in thickness or diameter, a deduction from the percentage of elongation in 8 in. specified in Section 6 (*a*) of 1.25 per cent shall be made for each decrease of $\frac{1}{32}$ in. in thickness or diameter below $\frac{5}{16}$ in.

Bend Tests.

8. (*a*) Bend test specimens, except as specified in Paragraphs (*b*) and (*c*), shall stand being bent cold through 180 deg. without cracking on the outside of the bent portion, as follows: For material $\frac{3}{4}$ in. or under in thickness, flat on itself; for material over $\frac{3}{4}$ in. to and including $1\frac{1}{4}$ in. in thickness, around a pin the diameter of which is equal to the thickness of the specimen; and for material over $1\frac{1}{4}$ in. in thickness, around a pin the diameter of which is equal to twice the thickness of the specimen.

(*b*) Bend test specimens for eyebar flats shall stand being bent cold through 180 deg. without cracking on the outside of the bent portion as follows: For material $\frac{3}{4}$ in. or under in thickness,

around a pin the diameter of which is equal to the thickness of the specimen; for material over $\frac{3}{4}$ in. to and including $1\frac{1}{4}$ in. in thickness, around a pin the diameter of which is equal to twice the thickness of the specimen; and for material over $1\frac{1}{4}$ in. in thickness, around a pin the diameter of which is equal to three times the thickness of the specimen.

(*c*) Bend test specimens for rivet steel shall stand being bent cold through 180 deg. flat on themselves without cracking on the outside of the bent portion.

Test Specimens.

9. (*a*) Test specimens shall be prepared for testing from the material in its rolled or forged condition, except as specified in Paragraphs (*b*) and (*c*).

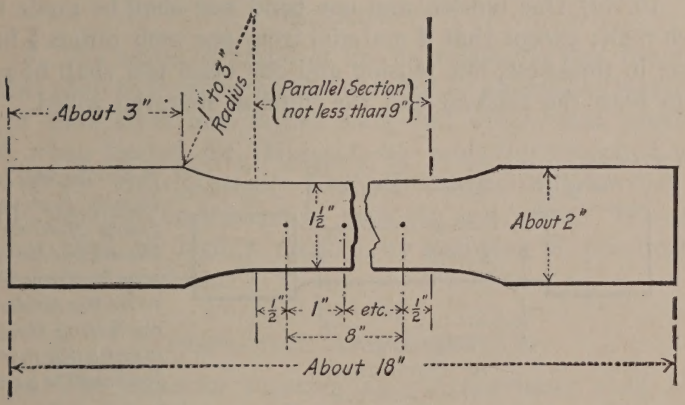


FIG. 1.

(*b*) Test specimens for annealed material shall be prepared from the material as annealed for use, or from a short length of a full section similarly treated.

(*c*) Test specimens for rivet bars which have been cold-drawn shall be normalized before testing.

(*d*) Test specimens shall be taken longitudinally and, except as specified in Paragraphs (*f*), (*g*), and (*h*), shall be of the full thickness or section of material as rolled.

(*e*) Test specimens for plates, shapes and flats may be machined to the form and dimensions shown in Fig. 1, or with both edges parallel. Bend test specimens for eyebar flats may have three rolled sides.

(*f*) Tension test specimens for material over $1\frac{1}{2}$ in. in thickness or diameter, except pins and rollers, may be machined to a

thickness or diameter of at least $\frac{3}{4}$ in. for a length of at least 9 in., or they may conform to the dimensions shown in Fig. 2.

(*g*) Bend test specimens for material over $1\frac{1}{2}$ in. in thickness or diameter, except eyebar flats, pins, and rollers, may be machined to a thickness or diameter of at least $\frac{3}{4}$ in. or to 1 by $\frac{1}{2}$ in. in section.

(*h*) Tension test specimens for pins and rollers shall conform to the dimensions shown in Fig. 2, and bend test specimens shall be 1 by $\frac{1}{2}$ in. in section.

(*i*) Test specimens for pins and rollers shall be taken so that the axis is 1 in. from the surface.

(*j*) The machined sides of rectangular bend test specimens may have the corners rounded to a radius not over $\frac{1}{16}$ in.

Number of Tests.

10. (*a*) One tension and one bend test shall be made from each melt; except that if material from one melt differs $\frac{3}{8}$ in. or more in thickness, one tension and one bend test shall be made from both the thickest and the thinnest material rolled.

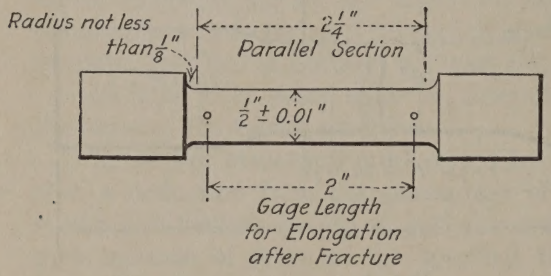

Radius not less than 1"
8
2 1/4"
Parallel Section
1"
2 ± 0.01"
2"
Gage Length for Elongation after Fracture
Note:-The Gage Length, Parallel Section, and Fillets shall be as Shown, but the Ends may be of any Shape to fit the Holders of the Testing Machine in such a Way that the Load shall be axial.

FIG. 2.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 6(*a*) and any part of the fracture is more than $\frac{3}{4}$ in. from the center of the gage length of a 2-in. specimen or is outside the middle third of the gage length of an 8-in. specimen, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

PERMISSIBLE VARIATIONS IN WEIGHT AND THICKNESS

Permissible Variations.

11. (*a*) The cross-section or weight of each piece of steel shall not vary more than 2.5 per cent from that specified; except in the case of sheared plates, which shall be covered by the permissible variations specified in paragraphs (*b*) and (*c*). (One cubic inch of rolled steel is assumed to weigh 0.2833 lb.)

(*b*) *Sheared Plates, When Ordered to Weight per Square Foot:* The weight of each lot[1] in each shipment shall not vary from the weight ordered more than the amount given in Table I.

(*c*) *Sheared Plates, When Ordered to Thickness:* The thickness of each plate shall not vary more than 0.01 in. under that ordered.

The overweight of each lot[1] in each shipment shall not exceed the amount given in Table II.

FINISH

Finish. 12. The finished material shall be free from injurious defects and shall have a workmanlike finish.

MARKING

Marking. 13. The name or brand of the manufacturer and the melt number shall be legibly stamped or rolled on all finished material, except that rivet and lattice bars and other small sections shall, when loaded for shipment, be properly separated and marked for identification. The identification marks shall be legibly stamped on the end of each pin and roller. The melt number shall be legibly marked, by stamping if practicable, on each test specimen.

INSPECTION AND REJECTION

Inspection. 14. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection. 15. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 5 shall be reported within five working days from the receipt of samples.

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[1] The term "lot" as applied to Table I means all of the plates of each group width and group weight; as applied to Table II, it means all of the plates of each group width and group thickness.

TABLE I.—PERMISSIBLE VARIATIONS OF RECTANGULAR PLATES ORDERED TO WEIGHT.

ORDERED WEIGHT, LB. PER SQ. FT.	PERMISSIBLE VARIATIONS IN AVERAGE WEIGHTS PER SQUARE FOOT OF PLATES FOR WIDTHS GIVEN, EXPRESSED IN PERCENTAGES OF ORDERED WEIGHTS.																				ORDERED WEIGHT, LB. PER SQ. FT.
	Under 48 in.		48 to 60 in., excl.		60 to 72 in., excl.		72 to 84 in., excl.		84 to 96 in., excl.		96 to 108 in., excl.		108 to 120 in., excl.		120 to 132 in., excl.		132 in. or over.			
	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.		
Under 5	5	3	5.5	3	6	3	7	3	...	...	...	...	...	...	...	...	...	...		Under 5
5 to 7.5 excl.	4.5	3	5	3	5.5	3	6	3	...	...	...	...	...	...	...	...	...	...		5 to 7.5 excl.
7.5 " 10 "	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	...	...	...	...		7.5 " 10 "
10 " 12.5 "	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	9	3		10 " 12.5 "
12.5 " 15 "	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3		12.5 " 15 "
15 " 17.5 "	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3		15 " 17.5 "
17.5 " 20 "	2.5	2	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3		17.5 " 20 "
20 " 25 "	2	2	2.5	2	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3		20 " 25 "
25 " 30 "	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	4.5	3	5	3		25 " 30 "
30 " 40 "	2	2	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	4.5	3		30 " 40 "
40 or over	2	2	2	2	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3		40 or over

NOTE.—The weight per square foot of individual plates snall not vary from the ordered weight by more than $1\frac{1}{3}$ times the amount given in this table.

TABLE II.—PERMISSIBLE OVERWEIGHTS OF RECTANGULAR PLATES ORDERED TO THICKNESS.

ORDERED THICKNESS, IN.	PERMISSIBLE EXCESS IN AVERAGE WEIGHTS PER SQUARE FOOT OF PLATES FOR WIDTHS GIVEN, EXPRESSED IN PERCENTAGES OF NOMINAL WEIGHTS.									ORDERED THICKNESS, IN.
	Under 48 in.	48 to 60 in., excl.	60 to 72 in., excl.	72 to 84 in., excl.	84 to 96 in., excl.	96 to 108 in., excl.	108 to 120 in., excl.	120 to 132 in., excl.	132 in. or over.	
Under 1/8	9	10	12	14	..	..	..	..	..	Under 1/8
1/8 to 3/16 excl.	8	9	10	12	..	..	..	..	..	1/8 to 3/16 excl.
3/16 " 1/4 "	7	8	9	10	12	..	..	..	..	3/16 " 1/4 "
1/4 " 5/16 "	6	7	8	9	10	12	14	16	19	1/4 " 5/16 "
5/16 " 3/8 "	5	6	7	8	9	10	12	14	17	5/16 " 3/8 "
3/8 " 7/16 "	4.5	5	6	7	8	9	10	12	15	3/8 " 7/16 "
7/16 " 1/2 "	4	4.5	5	6	7	8	9	10	13	7/16 " 1/2 "
1/2 " 5/8 "	3.5	4	4.5	5	6	7	8	9	11	1/2 " 5/8 "
5/8 " 3/4 "	3	3.5	4	4.5	5	6	7	8	9	5/8 " 3/4 "
3/4 " 1 "	2.5	3	3.5	4	4.5	5	6	7	8	3/4 " 1 "
1 or over	2.5	2.5	3	3.5	4	4.5	5	6	7	1 or over

(*b*) Material which shows injurious defects subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

16. Samples tested in accordance with Section 5, which represent rejected material, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time. Rehearing.

STANDARD SPECIFICATIONS
FOR
STRUCTURAL NICKEL STEEL[1]

Serial Designation: A 8 – 24

These specifications are issued under the fixed designation A 8; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

ADOPTED, 1912; REVISED, 1913, 1914, 1916, 1921, 1924.

MANUFACTURE

Process. 1. The steel shall be made by the open-hearth process.

Discard. 2. A sufficient discard shall be made from each ingot intended for eyebars to secure freedom from injurious piping and undue segregation.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition. 3. The steel shall conform to the following requirements as to chemical composition:

	Structural Steel.	Rivet Steel.
Carbon	not over 0.45	not over 0.30 per cent
Manganese	" " 0.70	" " 0.60 "
Phosphorus, Acid	" " 0.05	" " 0.04 "
Phosphorus, Basic	" " 0.04	" " 0.03 "
Sulfur	" " 0.05	" " 0.045 "
Nickel	not under 3.25	not under 3.25 "

Ladle Analyses. 4. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements specified in Section 3. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 3.

Check Analyses. 5. Analyses may be made by the purchaser from finished material representing each melt. The chemical composition thus determined shall conform to the requirements specified in Section 3.

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

PHYSICAL PROPERTIES AND TESTS

6. (*a*) The material shall conform to the following require- Tension Tests.
ments as to tensile properties:

Properties Considered.	Rivet Steel.	Plates, Shapes and Bars.	Eyebar flats and Rollers,[c] Unannealed.	Eyebar flats[a] and Pins,[c] Annealed.
Tensile strength, lb. per sq. in.	70 000 – 80 000	85 000 – 100 000	95 000 – 110 000	90 000 – 105 000
Yield point, min., lb. per sq. in.	45 000	50 000	55 000	52 000
Elongation in 8 in., min., per cent	1 500 000 / Tens. str.	1 500 000[b] / Tens. str.	1 500 000[b] / Tens. str.	20
Elongation in 2 in., min., per cent	.....	18	16	20
Reduction of area, min., per cent	40	25	25	35

[a] Tests of annealed specimens of eyebar flats shall be made for information only.
[b] See Section 7.
[c] Elongation shall be measured in 2 in.

(*b*) The yield point shall be determined by the drop of the beam of the testing machine.

7. For plates, shapes, and unannealed bars over 1 in. in thickness, a deduction from the percentage of elongation in 8 in., specified in Section 6 (*a*) of 0.25 per cent shall be made for each increase of $\frac{1}{32}$ in. of the specified thickness above 1 in., to a minimum of 14 per cent. Modification in Elongation.

8. All broken tension test specimens shall show either a silky or a very fine granular fracture, of uniform color, and free from coarse crystals. Character of Fracture.

9. (*a*) Bend test specimens shall stand being bent cold through 180 deg. without cracking on the outside of the bent portion, as follows: For material $\frac{3}{4}$ in. or under in thickness, around a pin the diameter of which is equal to the thickness of the specimen; and for material over $\frac{3}{4}$ in. in thickness, around a pin the diameter of which is equal to twice the thickness of the specimen. Bend Tests.

(*b*) Bend test specimens for rivet steel shall stand being bent cold through 180 deg. flat on themselves without cracking on the outside of the bent portion.

10. Punched rivet holes pitched two diameters from a planed edge shall stand drifting until the diameter is enlarged 50 per cent, without cracking the metal. Drift Tests.

11. (*a*) Test specimens shall be prepared for testing from the material in its rolled or forged condition, except as specified in Paragraphs (*b*) and (*c*). Test Specimens.

(*b*) Test specimens for annealed material shall be prepared from the material as annealed for use, or from a short length of a full section similarly treated.

(*c*) Test specimens for rivet bars which have been cold-drawn shall be normalized before testing.

(*d*) Test specimens shall be taken longitudinally and, except as specified in Paragraphs (*f*), (*g*), and (*h*), shall be of the full thickness or section of material as rolled.

(*e*) Test specimens for plates, shapes and flats may be machined to the form and dimensions shown in Fig. 1, or with both edges parallel. Bend test specimens for eyebar flats may have three rolled sides.

(*f*) Tension test specimens for material over $1\frac{1}{2}$ in. in thickness or diameter, except pins and rollers, may be machined

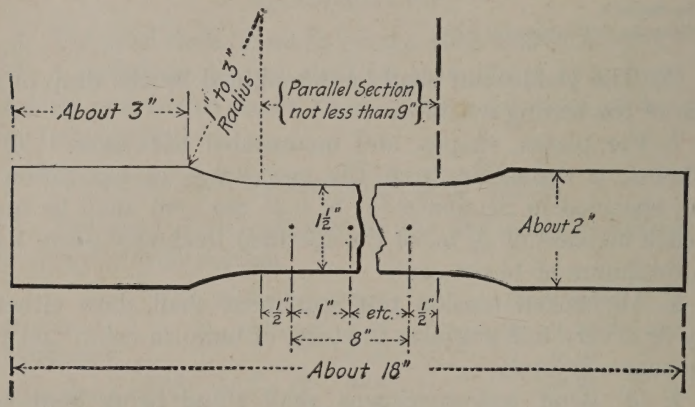

FIG. 1.

to a thickness or diameter of at least $\frac{3}{4}$ in. for a length of at least 9 in., or they may conform to the dimensions shown in Fig. 2.

(*g*) Bend test specimens for material over $1\frac{1}{2}$ in. in thickness or diameter, except eyebar flats, pins, and rollers, may be machined to a thickness or diameter of at least $\frac{3}{4}$ in. or to 1 by $\frac{1}{2}$ in. in section.

(*h*) Tension test specimens for pins and rollers shall conform to the dimensions shown in Fig. 2, and bend test specimens shall be 1 by $\frac{1}{2}$ in. in section.

(*i*) Test specimens for pins and rollers shall be taken so that the axis is 1 in. from the surface.

(*j*) The machined sides of rectangular bend test specimens may have the corners rounded to a radius not over $\frac{1}{16}$ in.

Number of Tests.

12. (*a*) One tension and one bend test shall be made from each melt; except that if material from one melt differs $\frac{3}{8}$ in. or more in thickness, one tension and one bend test shall be made from both the thickest and the thinnest material rolled.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 6 (*a*) and any part of the fracture is more than $\frac{3}{4}$ in. from the center of the gage length of a 2-in. specimen or is outside the middle third of the gage length of an 8-in. specimen, as indicated by scribe scratches marked on the specimen before, testing a retest shall be allowed.

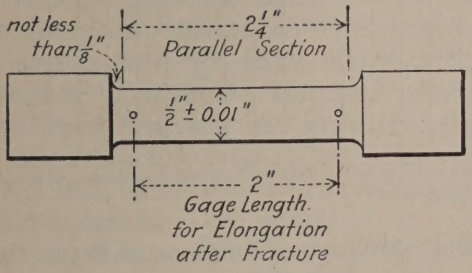
Radius not less than 1/8"
2 1/4"
Parallel Section
1/2" ± 0.01"
2"
Gage Length for Elongation after Fracture
Note:-The Gage Length, Parallel Section, and Fillets shall be as Shown, but the Ends may be of any Shape to fit the Holders of the Testing Machine in such a Way that the Load shall be axial.

FIG. 2.

PERMISSIBLE VARIATIONS IN WEIGHT AND THICKNESS

Permissible Variations.

13. (*a*) The cross-section or weight of each piece of steel shall not vary more than 2.5 per cent from that specified; except in the case of sheared plates, which shall be covered by the permissible variations specified in Paragraphs (*b*) and (*c*). (One cubic inch of rolled steel is assumed to weigh 0.2833 lb.)

(*b*) *Sheared Plates, When Ordered to Weight per Square Foot:* The weight of each lot[1] in each shipment shall not vary from the weight ordered more than the amount given in Table I.

(*c*) *Sheared Plates, When Ordered to Thickness:* The thickness of each plate shall not vary more than 0.01 in. under that ordered.

The overweight of each lot[1] in each shipment shall not exceed the amount given in Table II.

[1] The term "lot" as applied to Table I means all of the plates of each group width and group weight; as applied to Table II, it means all of the plates of each group width and group thickness.

TABLE I.—PERMISSIBLE VARIATIONS OF RECTANGULAR PLATES ORDERED TO WEIGHT.

ORDERED WEIGHT, LB. PER SQ. FT.	PERMISSIBLE VARIATIONS IN AVERAGE WEIGHTS PER SQUARE FOOT OF PLATES FOR WIDTHS GIVEN, EXPRESSED IN PERCENTAGES OF ORDERED WEIGHTS.																		ORDERED WEIGHT, LB. PER SQ. FT.
	Under 48 in.		48 to 60 in., excl.		60 to 72 in., excl.		72 to 84 in., excl.		84 to 96 in., excl.		96 to 108 in., excl.		108 to 120 in., excl.		120 to 132 in., excl.		132 in. or over.		
	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	
Under 5	5	3	5.5	3	6	3	7	3	...	...	...	...	...	...	...	...	...	...	Under 5
5 to 7.5 excl.	4.5	3	5	3	5.5	3	6	3	...	...	...	...	...	...	...	...	...	...	5 to 7.5 excl.
7.5 " 10 "	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	...	...	...	...	7.5 " 10 "
10 " 12.5 "	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	9	3	10 " 12.5 "
12.5 " 15 "	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	12.5 " 15 "
15 " 17.5 "	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	15 " 17.5 "
17.5 " 20 "	2.5	2	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	17.5 " 20 "
20 " 25 "	2	2	2.5	2	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	20 " 25 "
25 " 30 "	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	4.5	3	5	3	25 " 30 "
30 " 40 "	2	2	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	4.5	3	30 " 40 "
40 or over	2	2	2	2	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	40 or over

NOTE.—The weight per square foot of individual plates shall not vary from the ordered weight by more than $1\frac{1}{3}$ times the amount given in this table.

TABLE II.—PERMISSIBLE OVERWEIGHTS OF RECTANGULAR PLATES ORDERED TO THICKNESS.

ORDERED THICKNESS, IN.	PERMISSIBLE EXCESS IN AVERAGE WEIGHTS PER SQUARE FOOT OF PLATES FOR WIDTHS GIVEN, EXPRESSED IN PERCENTAGES OF NOMINAL WEIGHTS.									ORDERED THICKNESS, IN.
	Under 48 in.	48 to 60 in., excl.	60 to 72 in., excl.	72 to 84 in., excl.	84 to 96 in., excl.	96 to 108 in., excl.	108 to 120 in., excl.	120 to 132 in., excl.	132 in. or over.	
Under 1/8	9	10	12	14	..	..	..	..	..	Under 1/8
1/8 to 3/16 excl.	8	9	10	12	..	..	..	..	..	1/8 to 3/16 excl.
3/16 " 1/4 "	7	8	9	10	12	..	..	..	..	3/16 " 1/4 "
1/4 " 5/16 "	6	7	8	9	10	12	14	16	19	1/4 " 5/16 "
5/16 " 3/8 "	5	6	7	8	9	10	12	14	17	5/16 " 3/8 "
3/8 " 7/16 "	4.5	5	6	7	8	9	10	12	15	3/8 " 7/16 "
7/16 " 1/2 "	4	4.5	5	6	7	8	9	10	13	7/16 " 1/2 "
1/2 " 5/8 "	3.5	4	4.5	5	6	7	8	9	11	1/2 " 5/8 "
5/8 " 3/4 "	3	3.5	4	4.5	5	6	7	8	9	5/8 " 3/4 "
3/4 " 1 "	2.5	3	3.5	4	4.5	5	6	7	8	3/4 " 1 "
1 or over	2.5	2.5	3	3.5	4	4.5	5	6	7	1 or over

FINISH

14. The finished material shall be free from injurious defects and shall have a workmanlike finish. Finish.

MARKING

15. The name or brand of the manufacturer and the melt number shall be legibly stamped or rolled on all finished material, except that rivet and lattice bars and other small sections shall, when loaded for shipment, be properly separated and marked for identification. The identification marks shall be legibly stamped on the end of each pin and roller. The melt number shall be legibly marked, by stamping if practicable, on each test specimen. Marking.

INSPECTION AND REJECTION

16. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works. Inspection.

17. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 5 shall be reported within five working days from the receipt of samples. Rejection.

(*b*) Material which shows injurious defects subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

18. Samples tested in accordance with Section 5, which represent rejected material, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time. Rehearing.

FULL-SIZE TESTS

19. (*a*) Full-size tests of annealed eyebars shall conform to the following requirements as to tensile properties: Tests of Eyebars.

Tensile strength, lb. per sq. in.	85 000 – 100 000
Yield point, min., " "	48 000
Elongation in 18 ft., min., per cent	10
Reduction of area, " "	30

(*b*) The yield point shall be determined by the halt of the gage of the testing machine.

STANDARD SPECIFICATIONS
FOR
STRUCTURAL SILICON STEEL[1]

Serial Designation: A 94 – 27

These specifications are issued under the fixed designation A 94; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1925; ADOPTED, 1927.

Scope.

1. These specifications cover a special high-strength structural steel intended primarily for use as main stress-carrying material of structural members.

MANUFACTURE

Process.

2. The steel shall be made by the open-hearth process.

Discard.

3. A sufficient discard shall be made from each ingot to secure freedom from injurious piping and undue segregation.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

4. The steel shall conform to the following requirements as to chemical composition:

	Ladle Analysis	Check Analysis
Carbon, per cent	not over 0.40	not over 0.44
Phosphorus, per cent, Acid	" " 0.06	" " 0.075
Phosphorus, per cent, Basic	" " 0.04	" " 0.05
Sulfur, per cent	" " 0.05	" " 0.063
Silicon, per cent	" under 0.20	" under 0.18

Ladle Analyses.

5. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus, sulfur and silicon. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative and shall conform to the requirements specified in Section 4 for ladle analysis.

Check Analyses.

6. Analyses may be made by the purchaser from finished material representing each melt. The chemical composition thus determined shall conform to the requirements specified in Section 4 for check analysis.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

PHYSICAL PROPERTIES AND TESTS

7. (*a*) The material shall conform to the following requirements as to tensile properties: **Tension Tests.**

Tensile strength, lb. per sq. in.	80 000 – 95 000
Yield point, min., lb. per sq. in.	45 000
Elongation in 8 in., min., per cent	1 500 000[a] / tens. str.
Reduction of area, min., per cent	30[b]

[a] See Section 8.
[b] See Section 9.

(*b*) The yield point shall be determined by the drop of the beam of the testing machine when operated at a cross-head speed not greater than $\frac{1}{2}$ in. per minute. The testing machine shall not be stopped to obtain the drop of the beam.

8. For material over $\frac{3}{4}$ in. in thickness, a deduction from the percentage of elongation specified in Section 7 (*a*) of 0.25 per cent shall be made for each increase of $\frac{1}{16}$ in. of the specified thickness above $\frac{3}{4}$ in., to a minimum of 14 per cent. **Modifications in Elongation.**

9. For material over $\frac{3}{4}$ in. in thickness, a deduction from the percentage of reduction of area specified in Section 7 (*a*) of 0.50 per cent shall be made for each increase of $\frac{1}{16}$ in. of the specified thickness above $\frac{3}{4}$ in., to a minimum of 24 per cent. **Modifications in Reduction of Area.**

10. The test specimen shall stand being bent cold through 180 deg. without cracking on the outside of the bent portion around a pin, the diameter of which shall have the following relation to the thickness of the specimen: **Bend Tests.**

Specimen Thickness	Pin Diameter
Up to $\frac{3}{4}$ in., inclusive	1 times the thickness
Over $\frac{3}{4}$ in. to 1 in., inclusive	$1\frac{1}{2}$ " " "
Over 1 in. to $1\frac{1}{4}$ in., inclusive	2 " " "
Over $1\frac{1}{4}$ in.	$2\frac{1}{2}$ " " "

11. (*a*) Test specimens shall be prepared for testing from the material in its rolled or forged condition, except as specified in Paragraph (*b*). **Test Specimens.**

(*b*) Test specimens for annealed material shall be prepared from the material as annealed for use, or from a short length of a full section similarly treated.

(*c*) Test specimens shall be taken longitudinally, and, except as specified in Paragraphs (*e*) and (*f*), shall be of the full thickness or section of material as rolled.

(*d*) Test specimens for plates, shapes and flats may be machined to the form and dimensions shown in Fig. 1, or with both edges parallel.

(*e*) Tension test specimens for material over 1 in. in thickness or diameter may be machined to a thickness or diameter of at least $\frac{3}{4}$ in., for a length of at least 9 in.

(*f*) Bend test specimens for material over $1\frac{1}{4}$ in. in thickness or diameter may be machined to a thickness or diameter of at least $\frac{3}{4}$ in. or to 1 by $\frac{1}{2}$ in. in section.

(*g*) The machined sides of rectangular bend test specimens may have the corners rounded to a radius not over $\frac{1}{16}$ in.

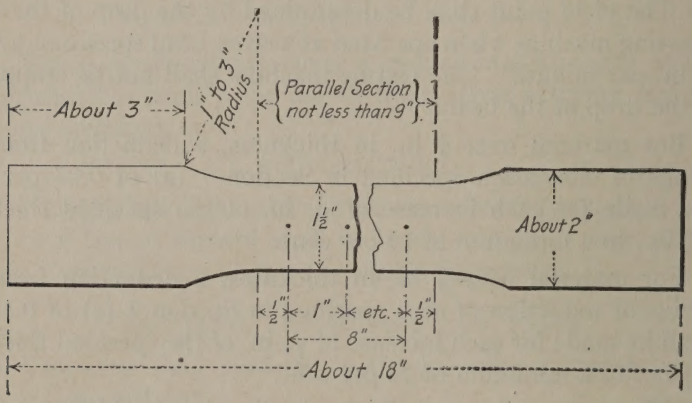


FIG. 1

Number of Tests.

12. (*a*) Two tension and one bend test shall be made from each melt; except that if material from one melt differs $\frac{3}{8}$ in. or more in thickness, one tension and one bend test shall be made from both the thickest and the thinnest material rolled.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 7 (*a*) and any part of the fracture is outside the middle third of the gage length, as indicated by marks placed on the specimen before testing, a retest shall be allowed.

PERMISSIBLE VARIATIONS IN WEIGHT AND THICKNESS

Permissible Variations.

13. The cross-section or weight of each piece of steel shall not vary more than 2.5 per cent from that specified; except in the case of sheared plates, which shall be covered by the following permissible variations. One cubic inch of rolled steel is assumed to weigh 0.2833 lb.

(*a*) *When Ordered to Weight per Square Foot:* The weight of each lot[1] in each shipment shall not vary from the weight ordered more than the amount given in Table I.

TABLE I.—PERMISSIBLE VARIATIONS OF RECTANGULAR PLATES ORDERED TO WEIGHT.

Ordered Weight, lb. per sq. ft.	Permissible Variations in Average Weights per Square Foot of Plates for Widths Given, Expressed in Percentages of Ordered Weights																		Ordered Weight, lb. per sq. ft.
	Under 48 in.		48 to 60 in., excl.		60 to 72 in., excl.		72 to 84 in., excl.		84 to 96 in., excl.		96 to 108 in., excl.		108 to 120 in., excl.		120 to 132 in., excl.		132 in. or over		
	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	
Under 5	5	3	5.5	3	6	3	7	3	...	...	...	...	...	...	...	...	...	...	Under 5
5 to 7.5 excl.	4.5	3	5	3	5.5	3	6	3	...	...	...	...	...	...	...	...	...	...	5 to 7.5 excl.
7.5 " 10 "	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	...	...	...	...	7.5 " 10 "
10 " 12.5 "	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	9	3	10 " 12.5 "
12.5 " 15 "	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	12.5 " 15 "
15 " 17.5 "	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	15 " 17.5 "
17.5 " 20 "	2.5	2	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	17.5 " 20 "
20 " 25 "	2	2	2.5	2	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	20 " 25 "
25 " 30 "	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	4.5	3	5	3	25 " 30 "
30 " 40 "	2	2	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	4.5	3	30 " 40 "
40 or over	2	2	2	2	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	40 or over

NOTE.—The weight per square foot of individual plates shall not vary from the ordered weight by more than $1\frac{1}{3}$ times the amount given in this table.

TABLE II.—PERMISSIBLE OVERWEIGHTS OF RECTANGULAR PLATES ORDERED TO THICKNESS.

Ordered Thickness, in.	Permissible Excess in Average Weights per Square Foot of Plates for Widths Given, Expressed in Percentages of Nominal Weights									Ordered Thickness, in.
	Under 48 in.	48 to 60 in., excl.	60 to 72 in. excl.	72 to 84 in., excl.	84 to 96 in., excl.	96 to 108 in., excl.	108 to 120 in., excl.	120 to 132 in., excl.	132 in. or over	
Under $\frac{1}{8}$	9	10	12	14	..	..	..	..	..	Under $\frac{1}{8}$
$\frac{1}{8}$ to $\frac{3}{16}$ excl.	8	9	10	12	..	..	..	..	..	$\frac{1}{8}$ to $\frac{3}{16}$ excl.
$\frac{3}{16}$ " $\frac{1}{4}$ "	7	8	9	10	12	..	..	..	..	$\frac{3}{16}$ " $\frac{1}{4}$ "
$\frac{1}{4}$ " $\frac{5}{16}$ "	6	7	8	9	10	12	14	16	19	$\frac{1}{4}$ " $\frac{5}{16}$ "
$\frac{5}{16}$ " $\frac{3}{8}$ "	5	6	7	8	9	10	12	14	17	$\frac{5}{16}$ " $\frac{3}{8}$ "
$\frac{3}{8}$ " $\frac{7}{16}$ "	4.5	5	6	7	8	9	10	12	15	$\frac{3}{8}$ " $\frac{7}{16}$ "
$\frac{7}{16}$ " $\frac{1}{2}$ "	4	4.5	5	6	7	8	9	10	13	$\frac{7}{16}$ " $\frac{1}{2}$ "
$\frac{1}{2}$ " $\frac{5}{8}$ "	3.5	4	4.5	5	6	7	8	9	11	$\frac{1}{2}$ " $\frac{5}{8}$ "
$\frac{5}{8}$ " $\frac{3}{4}$ "	3	3.5	4	4.5	5	6	7	8	9	$\frac{5}{8}$ " $\frac{3}{4}$ "
$\frac{3}{4}$ " 1 "	2.5	3	3.5	4	4.5	5	6	7	8	$\frac{3}{4}$ " 1 "
1 or over	2.5	2.5	3	3.5	4	4.5	5	6	7	1 or over

(*b*) *When Ordered to Thickness:* The thickness of each plate shall not vary more than 0.01 in. under that ordered.

The overweight of each lot[1] in each shipment shall not exceed the amount given in Table II.

[1] The term "lot" as applied to Table I means all of the plates of each group width and group weight; as applied to Table II, it means all of the plates of each group width and group thickness.

FINISH

Finish.

14. The finished material shall be free from injurious defects and shall have a workmanlike finish.

MARKING

Marking.

15. The name or brand of the manufacturer and the melt number shall be legibly stamped or rolled on all finished material. The melt number shall be legibly marked, by stamping if practicable, on each test specimen.

INSPECTION AND REJECTION

Inspection.

16. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection.

17. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 6 shall be reported within five working days from the receipt of samples.

(*b*) Material which shows injurious defects subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

Rehearing.

18. Samples tested in accordance with Section 6, which represent rejected material, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

STANDARD SPECIFICATIONS
FOR
STRUCTURAL STEEL FOR BUILDINGS[1]

Serial Designation: A 9 – 24

These specifications are issued under the fixed designation A 9; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ADOPTED, 1901; REVISED, 1909, 1913, 1914, 1916, 1921, 1924.

MANUFACTURE

Process.

1. (*a*) Structural steel, except as noted in Paragraph (*b*), shall be made by either or both the following processes: bessemer or open-hearth.

(*b*) Rivet steel, and steel for plates or angles over $\frac{3}{4}$ in. in thickness which are to be punched, shall be made by the open-hearth process.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

2. The steel shall conform to the following requirements as to chemical composition:

		Structural Steel	Rivet Steel
Phosphorus	Bessemer	not over 0.10 per cent	.....
	Open-hearth	" " 0.06 "	not over 0.06 per cent
Sulfur		.....	" " 0.045 "

Ladle Analyses.

3. (*a*) A carbon determination shall be made of each melt of bessemer steel, and determinations for manganese, phosphorus and sulfur representing the average of the melts applied for each 12-hour period.

(*b*) An analysis of each melt of open-hearth steel shall be made for carbon, manganese, phosphorus and sulfur.

(*c*) These analyses shall be made by the manufacturer from test ingots taken during the pouring of each melt. The chemical composition thus determined shall be reported to the purchaser or his representative and shall conform to the requirements specified in Section 2.

Check Analyses.

4. Analyses may be made by the purchaser from finished material representing each melt. The phosphorus and sulfur content thus determined shall not exceed that specified in Section 2 by more than 25 per cent.

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

PHYSICAL PROPERTIES AND TESTS

Tension Tests.

5. (*a*) The material shall conform to the following requirements as to tensile properties:

Properties Considered	Structural Steel	Rivet Steel
Tensile strength, lb. per sq. in	55 000 – 65 000	46 000 – 56 000
Yield point, min., " "	0.5 tens. str.	0.5 tens. str.
but in no case less than	30 000	25 000
Elongation in 8 in., min., per cent	$\frac{1\,400\,000^a}{\text{Tens. str.}}$	$\frac{1\,400\,000}{\text{Tens. str.}}$
Elongation in 2 in. " "	22	.....

[a] See Section 6.

(*b*) The yield point shall be determined by the drop of the beam of the testing machine.

Modifications in Elongation.

6. (*a*) For structural steel over $\frac{3}{4}$ in. in thickness, a deduction from the percentage of elongation in 8 in. specified in Section 5 (*a*) of 0.25 per cent shall be made for each increase of $\frac{1}{32}$ in. of the specified thickness above $\frac{3}{4}$ in., to a minimum of 18 per cent.

(*b*) For structural steel under $\frac{5}{16}$ in. in thickness, a deduction from the percentage of elongation in 8 in. specified in Section 5 (*a*) of 1.25 per cent shall be made for each decrease of $\frac{1}{32}$ in. of the specified thickness below $\frac{5}{16}$ in.

Bend Tests.

7. (*a*) Bend test specimens, except as specified in Paragraph (*b*), shall stand being bent cold through 180 deg. without cracking on the outside of the bent portion, as follows: For material $\frac{3}{4}$ in. or under in thickness, flat on itself; for material over $\frac{3}{4}$ in. to and including $1\frac{1}{4}$ in. in thickness, around a pin the diameter of which is equal to the thickness of the specimen; and for material over $1\frac{1}{4}$ in. in thickness, around a pin the diameter of which is equal to twice the thickness of the specimen.

(*b*) Bend test specimens for rivet steel shall stand being bent cold through 180 deg. flat on themselves without cracking on the outside of the bent portion.

Test Specimens.

8. (*a*) Test specimens shall be prepared for testing from the material in its rolled or forged condition, except as specified in Paragraphs (*b*) and (*c*).

(*b*) Test specimens for annealed material shall be prepared from the material as annealed for use, or from a short length of a full section similarly treated.

(*c*) Test specimens for rivet bars which have been cold-drawn shall be normalized before testing.

(*d*) Test specimens shall be taken longitudinally and, except as specified in Paragraphs (*f*), (*g*), and (*h*), shall be of the full thickness or section of material as rolled.

(*e*) Test specimens for plates, shapes and flats may be machined to the form and dimensions shown in Fig. 1, or with both edges parallel.

(*f*) Tension test specimens for material over $1\frac{1}{2}$ in. in thickness or diameter, except pins and rollers, may be machined to a thickness or diameter of at least $\frac{3}{4}$ in. for a length of at least 9 in., or they may conform to the dimensions shown in Fig. 2.

(*g*) Bend test specimens for material over $1\frac{1}{2}$ in. in thickness or diameter, except pins and rollers, may be machined to a thickness or diameter of at least $\frac{3}{4}$ in. or to 1 by $\frac{1}{2}$ in. in section.

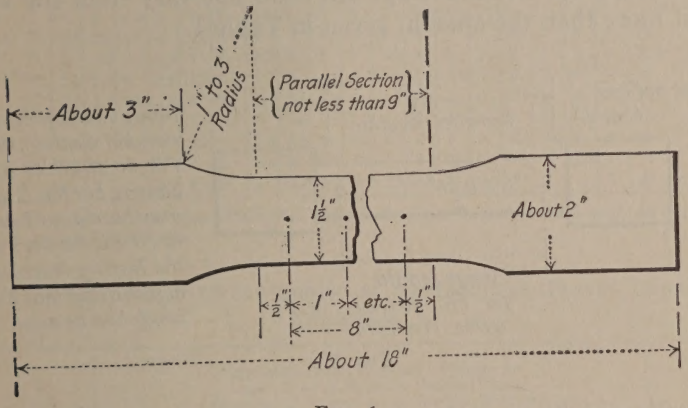


FIG. 1.

(*h*) Tension test specimens for pins and rollers shall conform to the dimensions shown in Fig. 2, and bend test specimens shall be 1 by $\frac{1}{2}$ in. in section.

(*i*) Test specimens for pins and rollers shall be taken so that the axis is 1 in. from the surface.

(*j*) The machined sides of rectangular bend test specimens may have the corners rounded to a radius not over $\frac{1}{16}$ in.

Number of Tests.

9. (*a*) One tension and one bend test shall be made from each melt; except that if material from one melt differs $\frac{3}{8}$ in. or more in thickness, one tension and one bend test shall be made from both the thickest and the thinnest material rolled.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 5 (*a*) and any part of the fracture

is more than $\frac{3}{4}$ in. from the center of the gage length of a 2-in. specimen or is outside the middle third of the gage length of an 8-in. specimen, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

PERMISSIBLE VARIATIONS IN WEIGHT AND THICKNESS

Permissible Variations.

10. (*a*) The cross-section or weight of each piece of steel shall not vary more than 2.5 per cent from that specified; except in the case of sheared plates, which shall be covered by the permissible variations specified in Paragraphs (*b*) and (*c*). (One cubic inch of rolled steel is assumed to weigh 0.2833 lb.)

(*b*) *Sheared Plates, When Ordered to Weight per Square Foot:* The weight of each lot[1] in each shipment shall not vary from the weight ordered more than the amount given in Table I.

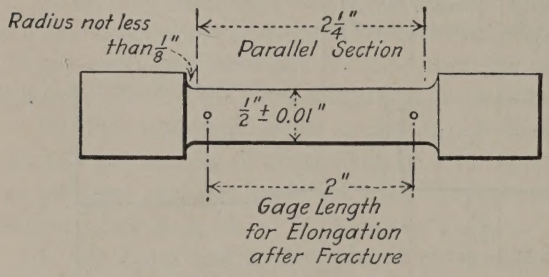

Radius not less than 1"
2 1/4"
Parallel Section
1/2" ± 0.01"
2"
Gage Length for Elongation after Fracture
Note:-The Gage Length, Parallel Section, and Fillets shall be as Shown, but the Ends may be of any Shape to fit the Holders of the Testing Machine in such a Way that the Load shall be axial.

FIG. 2.

(*c*) *Sheared Plates, When Ordered to Thickness:* The thickness of each plate shall not vary more than 0.01 in. under that ordered.

The overweight of each lot[1] in each shipment shall not exceed the amount given in Table II.

FINISH

Finish.

11. The finished material shall be free from injurious defects and shall have a workmanlike finish.

MARKING

Marking.

12. The name or brand of the manufacturer and the melt number shall be legibly stamped or rolled on all finished material, except that rivet and lattice bars and other small sections shall, when loaded for shipment, be properly separated and marked for identification. The

[1] The term "lot" as applied to Table I means all of the plates of each group width and group weight; as applied to Table II, it means all of the plates of each group width and group thickness.

identification marks shall be legibly stamped on the end of each pin and roller. The melt number shall be legibly marked, by stamping if practicable, on each test specimen.

TABLE I.—PERMISSIBLE VARIATIONS OF RECTANGULAR PLATES ORDERED TO WEIGHT.

Ordered Weight, lb. per sq. ft.	Permissible Variations in Average Weights per Square Foot of Plates for Widths Given. Expressed in Percentages of Ordered Weights																		Ordered Weight, lb. per sq ft.
	Under 48 in.		48 to 60 in., excl.		60 to 72 in., excl.		72 to 84 in., excl.		84 to 96 in., excl.		96 to 108 in., excl.		108 to 120 in., excl.		120 to 132 in., excl.		132 in. or over		
	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	
Under 5	5	3	5.5	3	6	3	7	3	..	..	..	..	..	..	..	..	..	..	Under 5
5 to 7.5 excl.	4.5	3	5	3	5.5	3	6	3	..	..	..	..	..	..	..	..	..	..	5 to 7.5 excl.
7.5 " 10 "	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	..	..	..	..	7.5 " 10 "
10 " 12.5 "	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	9	3	10 " 12.5 "
12.5 " 15 "	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	12.5 " 15 "
15 " 17.5 "	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	15 " 17.5 "
17.5 " 20 "	2.5	2	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	17.5 " 20 "
20 " 25 "	2	2	2.5	2	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	20 " 25 "
25 " 30 "	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	4.5	3	5	3	25 " 30 "
30 " 40 "	2	2	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	4.5	3	30 " 40 "
40 or over	2	2	2	2	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	40 or over

NOTE.—The weight per square foot of individual plates shall not vary from the ordered weight by more than $1\frac{1}{3}$ times the amount given in this table.

TABLE II.—PERMISSIBLE OVERWEIGHTS OF RECTANGULAR PLATES ORDERED TO THICKNESS.

Ordered Thickness, in.	Permissible Excess in Average Weights per Square Foot of Plates for Widths Given, Expressed in Percentages of Nominal Weights									Ordered Thickness, in.
	Under 48 in.	48 to 60 in., excl.	60 to 72 in., excl.	72 to 84 in., excl.	84 to 96 in., excl.	96 to 108 in., excl.	108 to 120 in., excl.	120 to 132 in., excl.	132 in. or over	
Under $\frac{1}{8}$	9	10	12	14	..	..	..	..	..	Under $\frac{1}{8}$
$\frac{1}{8}$ to $\frac{3}{16}$ excl.	8	9	10	12	..	..	..	..	..	$\frac{1}{8}$ to $\frac{3}{16}$ excl.
$\frac{3}{16}$ " $\frac{1}{4}$ "	7	8	9	10	12	..	..	..	..	$\frac{3}{16}$ " $\frac{1}{4}$ "
$\frac{1}{4}$ " $\frac{5}{16}$ "	6	7	8	9	10	12	14	16	19	$\frac{1}{4}$ " $\frac{5}{16}$ "
$\frac{5}{16}$ " $\frac{3}{8}$ "	5	6	7	8	9	10	12	14	17	$\frac{5}{16}$ " $\frac{3}{8}$ "
$\frac{3}{8}$ " $\frac{7}{16}$ "	4.5	5	6	7	8	9	10	12	15	$\frac{3}{8}$ " $\frac{7}{16}$ "
$\frac{7}{16}$ " $\frac{1}{2}$ "	4	4.5	5	6	7	8	9	10	13	$\frac{7}{16}$ " $\frac{1}{2}$ "
$\frac{1}{2}$ " $\frac{5}{8}$ "	3.5	4	4.5	5	6	7	8	9	11	$\frac{1}{2}$ " $\frac{5}{8}$ "
$\frac{5}{8}$ " $\frac{3}{4}$ "	3	3.5	4	4.5	5	6	7	8	9	$\frac{5}{8}$ " $\frac{3}{4}$ "
$\frac{3}{4}$ " 1 "	2.5	3	3.5	4	4.5	5	6	7	8	$\frac{3}{4}$ " 1 "
1 or over	2.5	2.5	3	3.5	4	4.5	5	6	7	1 or over

INSPECTION AND REJECTION

13. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which

Inspection.

concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection. 14. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 4 shall be reported within five working days from the receipt of samples.

(*b*) Material which shows injurious defects subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

Rehearing. 15. Samples tested in accordance with Section 4, which represent rejected material, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

STANDARD SPECIFICATIONS
FOR
STRUCTURAL STEEL FOR LOCOMOTIVES.[1]

Serial Designation: A 10 – 24

These specifications are issued under the fixed designation A 10; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

ADOPTED, 1912; REVISED, 1913, 1914, 1916, 1921, 1924.

Basis of Purchase.

1. These specifications apply to shapes, plates (except boiler and firebox plates) and bars over $\frac{1}{8}$ in. in thickness or diameter.

MANUFACTURE

Process.

2. The steel shall be made by the open-hearth process.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

3. The steel shall conform to the following requirements as to chemical composition:

Phosphorus	not over 0.05 per cent
Sulfur	" " 0.06 "

Ladle Analyses.

4. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus and sulfur. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 3.

Check Analyses.

5. Analyses may be made by the purchaser from finished material representing each melt. The phosphorus and sulfur content thus determined shall conform to the requirements specified in Section 3.

PHYSICAL PROPERTIES AND TESTS

Tension Tests.

6. (*a*) The material, except as specified in Paragraph (*c*), shall conform to the following requirements as to tensile properties:

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

Tensile strength, lb. per sq. in.	55 000 – 65 000
Yield point, min., " "	0.5 tens. str.
Elongation in 8 in., min., per cent (See Section 7)	$\frac{1\,500\,000}{\text{Tens. str.}}$
Elongation in 2 in., min., per cent	22

(*b*) The yield point shall be determined by the drop of the beam of the testing machine.

(*c*) Plates $\frac{3}{16}$ in. or under in thickness, shapes less than 1 sq. in. in section, and bars less than $\frac{1}{2}$ sq. in. in section need not be subjected to tension tests.

Modifications in Elongation.

7. (*a*) For material over $\frac{3}{4}$ in. in thickness, a deduction from the percentage of elongation in 8 in. specified in Section 6 (*a*) of 0.25 per cent shall be made for each increase of $\frac{1}{32}$ in. of the specified thickness above $\frac{3}{4}$ in., to a minimum of 18 per cent.

(*b*) For material under $\frac{5}{16}$ in. in thickness, a deduction from the percentage of elongation in 8 in. specified in Section 6 (*a*) of 1.25 per cent shall be made for each decrease of $\frac{1}{32}$ in. of the specified thickness below $\frac{5}{16}$ in.

Bend Tests.

8. Bend test specimens shall stand being bent cold through 180 deg. without cracking on the outside of the bent portion, as follows: For material $\frac{3}{4}$ in. or under in thickness, flat on itself; for material over $\frac{3}{4}$ in. to and including $1\frac{1}{4}$ in. in thickness, around a pin the diameter of which is equal to the thickness of the specimen; and for material over $1\frac{1}{4}$ in. in thickness, around a pin the diameter of which is equal to twice the thickness of the specimen.

Test Specimens.

9. (*a*) Test specimens shall be prepared for testing from the material in its rolled or forged condition, except when it is specified to be annealed; in which case the test specimens shall be prepared from the material as annealed for use, or from a short length of a full section similarly treated.

(*b*) Test specimens shall be taken longitudinally and, except as specified in Paragraphs (*d*) and (*e*), shall be of the full thickness or section of material as rolled.

(*c*) Test specimens for plates, shapes and flats may be machined to the form and dimensions shown in Fig. 1, or with both edges parallel.

(*d*) Tension test specimens for material over $1\frac{1}{2}$ in. in thickness or diameter may be machined to a thickness or diameter of at least $\frac{3}{4}$ in. for a length of at least 9 in., or they may conform to the dimensions shown in Fig. 2.

(*e*) Bend test specimens for material over $1\frac{1}{2}$ in. in thickness or diameter may be machined to a thickness or diameter of at least $\frac{3}{4}$ in. or to 1 by $\frac{1}{2}$ in. in section.

(*f*) The machined sides of rectangular bend test specimens may have the corners rounded to a radius of not over $\frac{1}{16}$ in.

Number of Tests.

10. (*a*) One tension and one bend test shall be made from each melt; except that if material from one melt differs $\frac{3}{8}$ in. or over in thickness, one tension and one bend test shall be made from both the thickest and the thinnest material rolled.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

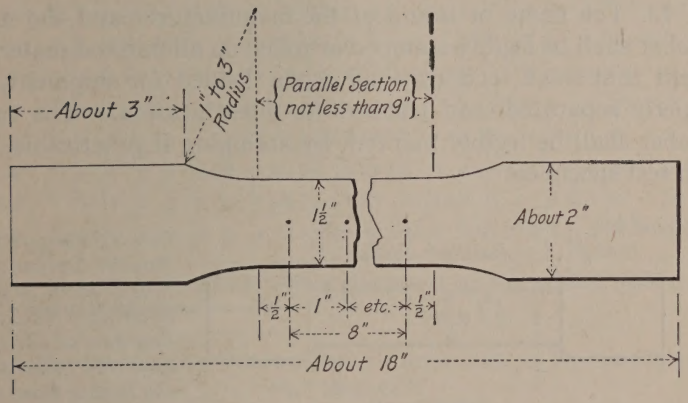


FIG. 1.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 6 (*a*) and any part of the fracture is more than $\frac{3}{4}$ in. from the center of the gage length of a 2-in. specimen or is outside the middle third of the gage length of an 8 in. specimen as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

PERMISSIBLE VARIATIONS IN WEIGHT AND THICKNESS.

Permissible Variations.

11. (*a*) The cross-section or weight of each piece of steel shall not vary more than 2.5 per cent from that specified; except in the case of sheared plates, which shall be covered by the permissible variations specified in Paragraphs (*b*) and (*c*). (One cubic inch of rolled steel is assumed to weigh 0.2833 lb.)

(*b*) *Sheared Plates, When Ordered to Weight per Square Foot:* The weight of each lot[1] in each shipment shall not vary from the weight ordered more than the amount given in Table I.

(*c*) *Sheared Plates, When Ordered to Thickness:* The thickness of each plate shall not vary more than 0.01 in. under that ordered.

The overweight of each lot[1] in each shipment shall not exceed the amount given in Table II.

FINISH

Finish.

12. The finished material shall be free from injurious defects and shall have a workmanlike finish.

MARKING

Marking.

13. The name or brand of the manufacturer and the melt number shall be legibly stamped or rolled on all finished material, except that small sections shall, when loaded for shipment, be properly separated and marked for identification. The melt number shall be legibly marked, by stamping if practicable, on each test specimen.

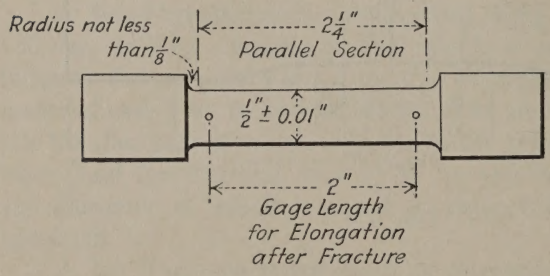

Radius not less than 1/8"
2 1/4"
Parallel Section
1/2" ± 0.01"
2"
Gage Length for Elongation after Fracture
Note:-The Gage Length, Parallel Section, and Fillets shall be as Shown, but the Ends may be of any Shape to fit the Holders of the Testing Machine in such a Way that the Load shall be axial.

FIG. 2.

INSPECTION AND REJECTION

Inspection.

14. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of

[1] The term "lot" as applied to Table I means all of the plates of each group width and group weight; as applied to Table II, it means all of the plates of each group width and group thickness.

TABLE I.—PERMISSIBLE VARIATIONS OF RECTANGULAR PLATES ORDERED TO WEIGHT.

ORDERED WEIGHT, LB. PER SQ. FT.	PERMISSIBLE VARIATIONS IN AVERAGE WEIGHTS PER SQUARE FOOT OF PLATES FOR WIDTHS GIVEN, EXPRESSED IN PERCENTAGES OF ORDERED WEIGHTS.																		ORDERED WEIGHT, LB. PER SQ. FT.
	Under 48 in.		48 to 60 in., excl.		60 to 72 in., excl.		72 to 84 in., excl.		84 to 96 in., excl.		96 to 108 in., excl.		108 to 120 in., excl.		120 to 132 in., excl.		132 in. or over.		
	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	
Under 5	5	3	5.5	3	6	3	7	3	...	...	...	...	...	...	...	...	...	...	Under 5
5 to 7.5 excl.	4.5	3	5	3	5.5	3	6	3	...	...	...	...	...	...	...	...	...	...	5 to 7.5 excl.
7.5 " 10 "	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	...	...	...	...	7.5 " 10 "
10 " 12.5 "	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	9	3	10 " 12.5 "
12.5 " 15 "	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	12.5 " 15 "
15 " 17.5 "	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	15 " 17.5 "
17.5 " 20 "	2.5	2	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	17.5 " 20 "
20 " 25 "	2	2	2.5	2	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	20 " 25 "
25 " 30 "	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	4.5	3	5	3	25 " 30 "
30 " 40 "	2	2	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	4.5	3	30 " 40 "
40 or over	2	2	2	2	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	40 or over

NOTE.—The weight per square foot of individual plates shall not vary from the ordered weight by more than $1\frac{1}{3}$ times the amount given in this table.

TABLE II.—PERMISSIBLE OVERWEIGHTS OF RECTANGULAR PLATES ORDERED TO THICKNESS.

ORDERED THICKNESS, IN.	PERMISSIBLE EXCESS IN AVERAGE WEIGHTS PER SQUARE FOOT OF PLATES FOR WIDTHS GIVEN, EXPRESSED IN PERCENTAGES OF NOMINAL WEIGHTS.									ORDERED THICKNESS, IN.
	Under 48 in.	48 to 60 in., excl.	60 to 72 in., excl.	72 to 84 in., excl.	84 to 96 in., excl.	96 to 108 in., excl.	108 to 120 in., excl.	120 to 132 in., excl.	132 in. or over.	
Under 1/8	9	10	12	14	..	..	..	..	..	Under 1/8
1/8 to 3/16 excl.	8	9	10	12	..	..	..	..	..	1/8 to 3/16 excl.
3/16 " 1/4 "	7	8	9	10	12	..	..	..	..	3/16 " 1/4 "
1/4 " 5/16 "	6	7	8	9	10	12	14	16	19	1/4 " 5/16 "
5/16 " 3/8 "	5	6	7	8	9	10	12	14	17	5/16 " 3/8 "
3/8 " 7/16 "	4.5	5	6	7	8	9	10	12	15	3/8 " 7/16 "
7/16 " 1/2 "	4	4.5	5	6	7	8	9	10	13	7/16 " 1/2 "
1/2 " 5/8 "	3.5	4	4.5	5	6	7	8	9	11	1/2 " 5/8 "
5/8 " 3/4 "	3	3.5	4	4.5	5	6	7	8	9	5/8 " 3/4 "
3/4 " 1 "	2.5	3	3.5	4	4.5	5	6	7	8	3/4 " 1 "
1 or over	2.5	2.5	3	3.5	4	4.5	5	6	7	1 or over

manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection. 15. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 5 shall be reported within five working days from the receipt of samples.

(*b*) Material which shows injurious defects subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

Rehearing. 16. Samples tested in accordance with Section 5, which represent rejected material, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

STANDARD SPECIFICATIONS
FOR
STRUCTURAL STEEL FOR CARS[1]

Serial Designation: A 11 – 24

These specifications are issued under the fixed designation A 11; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ADOPTED, 1914; REVISED, 1916, 1921, 1924.

Scope. 1. These specifications apply to shapes, plates and bars over $\frac{1}{8}$ in. in thickness or diameter.

MANUFACTURE

Process. 2. The steel shall be made by the open-hearth process.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition. 3. (*a*) The steel shall conform to the following requirements as to chemical composition:

		Structural Steel and Plates for Cold Pressing	Rivet Steel
Phosphorus	Acid	not over 0.06 per cent	not over 0.04 per cent
	Basic	" " 0.04 "	" " 0.04 "
Sulfur		" " 0.06 "	" " 0.045 "

(*b*) When copper steel is specified, the following requirement as to copper shall govern:

Copper.....not less than 0.20 per cent

Ladle Analyses. 4. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus and sulfur and also copper when copper steel is specified. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 3.

Check Analyses. 5. Analyses may be made by the purchaser from finished material representing each melt. The phosphorus and sulfur content thus determined shall not exceed that specified in Section 3 by more than 25 per cent.

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

PHYSICAL PROPERTIES AND TESTS

Tension Tests.

6. (*a*) The material, except as specified in Paragraph (*c*), shall conform to the following requirements as to tensile properties:

Properties Considered	Structural Steel	Rivet Steel	Plates for Cold Pressing
Tensile strength, lb. per sq. in.	50 000 – 65 000	45 000 – 60 000	48 000 – 58 000
Yield point, min.,	0.5 tens. str.	0.5 tens. str.	0.5 tens. str
Elongation in 8 in., min., per cent[a]	$\frac{1\,500\,000}{\text{Tens. str.}}$	$\frac{1\,500\,000}{\text{Tens. str.}}$	$\frac{1\,500\,000}{\text{Tens. str}}$
Elongation in 2 in., " "	22	.....	.....

[a] See Section 7

(*b*) The yield point shall be determined by the drop of the beam of the testing machine.

(*c*) Plates $\frac{3}{16}$ in. or under in thickness, shapes less than 1 sq. in. in section, and bars, except rivet rods, less than $\frac{1}{2}$ in. in section need not be subjected to tension tests.

Modifications in Elongation.

7. (*a*) For material over $\frac{3}{4}$ in. in thickness, a deduction from the percentage of elongation in 8 in. specified in Section 6 (*a*) of 0.25 per cent shall be made for each increase of $\frac{1}{32}$ in. of the specified thickness above $\frac{3}{4}$ in., to a minimum of 18 per cent.

(*b*) For material under $\frac{5}{16}$ in. in thickness, a deduction from the percentage of elongation in 8 in. specified in Section 6 (*a*) of 1.25 per cent shall be made for each decrease of $\frac{1}{32}$ in. of the specified thickness below $\frac{5}{16}$ in.

Bend Tests.

8. (*a*) Bend test specimens for structural steel shall stand being bent cold through 180 deg. without cracking on the outside of the bent portion, as follows: For material $\frac{3}{4}$ in. or under in thickness, flat on itself; for material over $\frac{3}{4}$ in. to and including $1\frac{1}{4}$ in. in thickness, around a pin the diameter of which is equal to the thickness of the specimen; and for material over $1\frac{1}{4}$ in. in thickness, around a pin the diameter of which is equal to twice the thickness of the specimen.

(*b*) Bend test specimens for rivet steel and plates for cold pressing shall stand being bent cold through 180 deg. flat on themselves without cracking on the outside of the bent portion.

Test Specimens.

9. (*a*) Test specimens shall be prepared for testing from the material in its rolled or forged condition, except as specified in Paragraphs (*b*) and (*c*).

(*b*) Test specimens for annealed material shall be prepared from the material as annealed for use, or from a short length of a full section similarly treated.

(*c*) Test specimens for rivet bars which have been cold-drawn shall be normalized before testing.

(*d*) Test specimens shall be taken longitudinally and, except as specified in Paragraphs (*f*) and (*g*), shall be of the full thickness or section of material as rolled.

(*e*) Test specimens for plates, shapes and flats may be machined to the form and dimensions shown in Fig. 1, or with both edges parallel.

(*f*) Tension test specimens for material over $1\frac{1}{2}$ in. in thickness or diameter may be machined to a thickness or diameter of at least

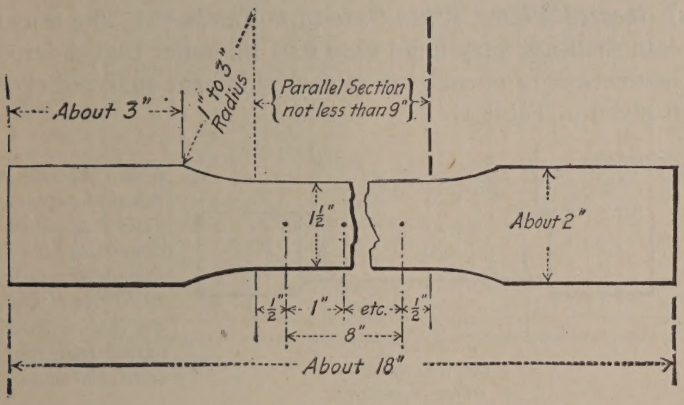


FIG. 1.

$\frac{3}{4}$ in. for a length of at least 9 in., or they may conform to the dimensions shown in Fig. 2.

(*g*) Bend test specimens for material over $1\frac{1}{2}$ in. in thickness or diameter may be machined to a thickness or diameter of at least $\frac{3}{4}$ in. or to 1 by $\frac{1}{2}$ in. in section.

(*h*) The machined sides of rectangular bend test specimens may have the corners rounded to a radius not over $\frac{1}{16}$ in.

Number of Tests.

10. (*a*) One tension and one bend test shall be made from each melt; except that if material from one melt differs $\frac{3}{8}$ in. or more in thickness, one tension and one bend test shall be made from both the thickest and the thinnest material rolled.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 6 (*a*) and any part of the fracture is more than $\frac{3}{4}$ in. from the center of the gage length of a 2-in. specimen or is outside the middle third of the gage length of an 8-in. specimen, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

PERMISSIBLE VARIATIONS IN WEIGHT AND THICKNESS

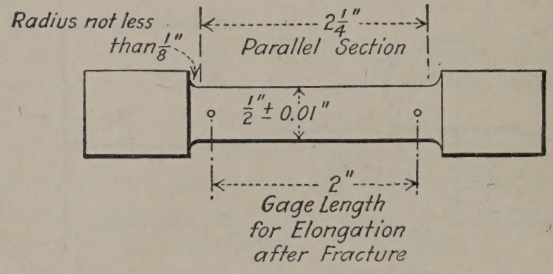
Permissible Variations.

11. (*a*) The cross-section or weight of each piece of steel shall not vary more than 2.5 per cent from that specified; except in the case of sheared plates, which shall be covered by the permissible variations specified in Paragraphs (*b*) and (*c*). (One cubic inch of rolled steel is assumed to weigh 0.2833 lb.)

(*b*) *Sheared Plates, When Ordered to Weight per Square Foot:* The weight of each lot[1] in each shipment shall not vary from the weight ordered more than the amount given in Table I.

(*c*) *Sheared Plates, When Ordered to Thickness:* The thickness of each plate shall not vary more than 0.01 in. under that ordered.

The overweight of each lot[1] in each shipment shall not exceed the amount given in Table II.



Note:-The Gage Length, Parallel Section, and Fillets shall be as Shown, but the Ends may be of any Shape to fit the Holders of the Testing Machine in such a Way that the Load shall be axial.

FIG. 2.

FINISH

Finish.

12. The finished material shall be free from injurious defects and shall have a workmanlike finish.

MARKING

Marking.

13. The name or brand of the manufacturer and the melt number shall be legibly rolled or stamped on all finished material, except that rivet bars and other small sections shall, when loaded for shipment, be properly separated and marked for identification. The melt number shall be legibly marked, by stamping if practicable, on each test specimen.

INSPECTION AND REJECTION

Inspection.

14. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford

[1] The term "lot" as applied to Table I means all of the plates of each group width and group weight; as applied to Table II, it means all of the plates of each group width and group thickness.

the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made

TABLE I.—PERMISSIBLE VARIATIONS OF RECTANGULAR PLATES ORDERED TO WEIGHT.

Ordered Weight, lb. per sq. ft.	Permissible Variations in Average Weights per Square Foot of Plates for Widths Given, Expressed in Percentages of Ordered Weights																		Ordered Weight, lb. per sq. ft.
	Under 48 in.		48 to 60 in., excl.		60 to 72 in., excl.		72 to 84 in., excl.		84 to 96 in., excl.		96 to 108 in., excl.		108 to 120 in., excl.		120 to 132 in., excl.		132 in. or over		
	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	
Under 5	5	3	5.5	3	6	3	7	3	..	..	..	..	..		..	..	..	..	Under 5
5 to 7.5 excl.	4.5	3	5	3	5.5	3	6	3	..	..	..	..	..	..	..	..	..	..	5 to 7.5 excl.
7.5 " 10 "	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	..	..	..	..	7.5 " 10 "
10 " 12.5 "	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	9	3	10 " 12.5 "
12.5 " 15 "	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	12.5 " 15 "
15 " 17.5 "	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	15 " 17.5 "
17.5 " 20 "	2.5	2	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	17.5 " 20 "
20 " 25 "	2	2	2.5	2	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	20 " 25 "
25 " 30 "	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	4.5	3	5	3	25 " 30 "
30 " 40 "	2	2	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	4.5	3	30 " 40 "
40 or over	2	2	2	2	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	40 or over

NOTE.—The weight per square foot of individual plates shall not vary from the ordered weight by more than $1\frac{1}{3}$ times the amount given in this table.

TABLE II.—PERMISSIBLE OVERWEIGHTS OF RECTANGULAR PLATES ORDERED TO THICKNESS.

Ordered Thickness, in.	Permissible Excess in Average Weights per Square Foot of Plates for Widths Given, Expressed in Percentages of Nominal Weights									Ordered Thickness, in.
	Under 48 in.	48 to 60 in., excl.	60 to 72 in., excl.	72 to 84 in., excl.	84 to 96 in., excl.	96 to 108 in., excl.	108 to 120 in., excl.	120 to 132 in., excl.	132 in. or over	
Under $\frac{1}{8}$	9	10	12	14	..	..	..	..	..	Under $\frac{1}{8}$
$\frac{1}{8}$ to $\frac{3}{16}$ excl.	8	9	10	12	..	..	..	..	..	$\frac{1}{8}$ to $\frac{3}{16}$ excl.
$\frac{3}{16}$ " $\frac{1}{4}$ "	7	8	9	10	12	..	..	..	..	$\frac{3}{16}$ " $\frac{1}{4}$ "
$\frac{1}{4}$ " $\frac{5}{16}$ "	6	7	8	9	10	12	14	16	19	$\frac{1}{4}$ " $\frac{5}{16}$ "
$\frac{5}{16}$ " $\frac{3}{8}$ "	5	6	7	8	9	10	12	14	17	$\frac{5}{16}$ " $\frac{3}{8}$ "
$\frac{3}{8}$ " $\frac{7}{16}$ "	4.5	5	6	7	8	9	10	12	15	$\frac{3}{8}$ " $\frac{7}{16}$ "
$\frac{7}{16}$ " $\frac{1}{2}$ "	4	4.5	5	6	7	8	9	10	13	$\frac{7}{16}$ " $\frac{1}{2}$ "
$\frac{1}{2}$ " $\frac{5}{8}$ "	3.5	4	4.5	5	6	7	8	9	11	$\frac{1}{2}$ " $\frac{5}{8}$ "
$\frac{5}{8}$ " $\frac{3}{4}$ "	3	3.5	4	4.5	5	6	7	8	9	$\frac{5}{8}$ " $\frac{3}{4}$ "
$\frac{3}{4}$ " 1 "	2.5	3	3.5	4	4.5	5	6	7	8	$\frac{3}{4}$ " 1 "
1 or over	2.5	2.5	3	3.5	4	4.5	5	6	7	1 or over

at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection.

15. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 5 shall be reported within five working days from the receipt of samples.

(*b*) Material which shows injurious defects subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

Rehearing.

16. Samples tested in accordance with Section 5, which represent rejected material, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

STANDARD SPECIFICATIONS
FOR
STRUCTURAL STEEL FOR SHIPS[1]

Serial Designation: A 12 – 21

These specifications are issued under the fixed designation A 12; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

ADOPTED, 1901; REVISED, 1909, 1913, 1914, 1916, 1921.

MANUFACTURE

1. The steel shall be made by the open-hearth process. **Process.**

CHEMICAL PROPERTIES AND TESTS

2. The steel shall conform to the following requirements as to chemical composition: **Chemical Composition.**

Phosphorus	Acid	not over 0.06 per cent
	Basic	" " 0.04 "
Sulfur		" " 0.06 "

3. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus and sulfur. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 2. **Ladle Analyses.**

4. Analyses may be made by the purchaser from finished material representing each melt. The phosphorus and sulfur content thus determined shall not exceed that specified in Section 2 by more than 25 per cent. **Check Analyses.**

PHYSICAL PROPERTIES AND TESTS

5. (*a*) The material shall conform to the following requirements as to tensile properties: **Tension Tests.**

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

NOTE.—The requirements for castings for ships have been especially provided for in the Standard Specifications for Steel Castings (Serial Designation: A 27) of the American Society for Testing Materials, see p. 231.

Tensile strength, lb. per sq. in.	58 000–68 000
Yield point, min., " "	0.5 tens. str.
Elongation in 8 in., min., per cent. (See Section 6.)	$\frac{1\,500\,000}{\text{Tens. str.}}$

(*b*) The yield point shall be determined by the drop of the beam of the testing machine.

Modifications in Elongation.

6. (*a*) For material over $\frac{3}{4}$ in. in thickness, a deduction from the percentage of elongation specified in Section 5 (*a*) of 0.25 per cent shall be made for each increase of $\frac{1}{32}$ in. of the specified thickness above $\frac{3}{4}$ in., to a minimum of 18 per cent.

(*b*) For material $\frac{1}{4}$ in. or under in thickness, the elongation shall be measured on a gage length of 24 times the thickness of the specimen.

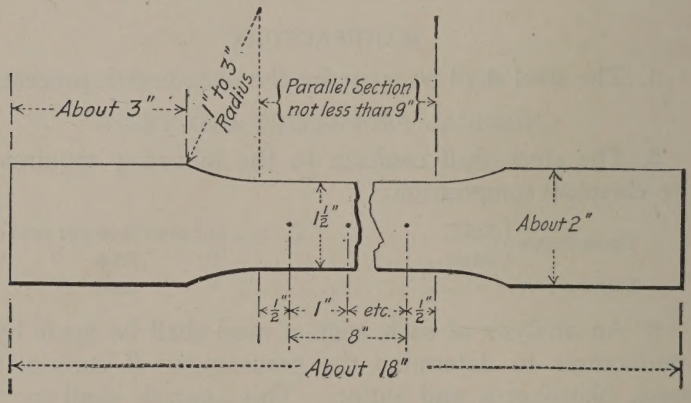


FIG. 1.

Bend Tests.

7. The test specimen shall bend cold through 180 deg. without cracking on the outside of the bent portion, as follows: For material $\frac{3}{4}$ in. or under in thickness, around a pin the diameter of which is equal to the thickness of the specimen; for material over $\frac{3}{4}$ in. to and including $1\frac{1}{4}$ in. in thickness, around a pin the diameter of which is equal to $1\frac{1}{2}$ times the thickness of the specimen; and for material over $1\frac{1}{4}$ in. in thickness, around a pin the diameter of which is equal to twice the thickness of the specimen.

Test Specimens.

8. (*a*) Test specimens shall be prepared for testing from the material in its rolled or forged condition, except when it is specified to be annealed; in which case the test specimens shall be prepared from the material as annealed for use, or from a short length of a full section similarly treated.

(*b*) Test specimens shall be taken longitudinally and, except as specified in Paragraphs (*d*) and (*e*), shall be of the full thickness or diameter of material as rolled.

(*c*) Test specimens for plates, shapes and flats may be machined to the form and dimensions shown in Fig. 1, or with both edges parallel.

(*d*) Test specimens for plates over $1\frac{1}{2}$ in. in thickness may be machined to a thickness or diameter of at least $\frac{3}{4}$ in. for a length of at least 9 in.

(*e*) Test specimens for bars over $1\frac{1}{2}$ in. in thickness or diameter may be machined to a thickness or diameter of at least $\frac{3}{4}$ in. for a length of at least 9 in.; or tension test specimens may conform to the dimensions shown in Fig. 2, in which case the ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial. Bend test specimens may be 1 by $\frac{1}{2}$ in. in section.

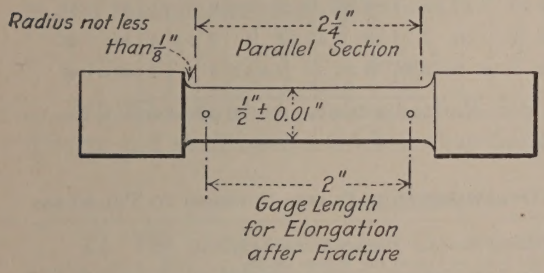

Radius not less than 1/8"
2 1/4"
Parallel Section
1/2" ± 0.01"
2"
Gage Length for Elongation after Fracture
Note:-The Gage Length, Parallel Section, and Fillets shall be as Shown, but the Ends may be of any Shape to fit the Holders of the Testing Machine in such a Way that the Load shall be axial.

FIG. 2.

(*f*) The tension test specimen shown in Fig. 2 and the 1 by $\frac{1}{2}$-in. bend test specimen for bars over $1\frac{1}{2}$ in. in thickness or diameter shall be taken so that the axis is midway between the center and surface.

(*g*) The machined sides of rectangular bend test specimens may have the corners rounded to a radius not over $\frac{1}{16}$ in.

Number of Tests.

9. (*a*) One tension and one bend test shall be made from each melt; except that if material from one melt differs $\frac{3}{8}$ in. or more in thickness, one tension and one bend test shall be made from both the thickest and the thinnest material rolled.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 5 (*a*) and any part

TABLE I.—PERMISSIBLE VARIATIONS OF PLATES ORDERED TO WEIGHT.

ORDERED WEIGHT, LB. PER SQ. FT.	PERMISSIBLE VARIATIONS IN AVERAGE WEIGHTS PER SQUARE FOOT OF PLATES FOR WIDTHS GIVEN, EXPRESSED IN PERCENTAGES OF ORDERED WEIGHTS.																				ORDERED WEIGHT, LB. PER SQ. FT.
	Under 48 in.		48 to 60 in., excl.		60 to 72 in., excl.		72 to 84 in., excl.		84 to 96 in., excl.		96 to 108 in., excl.		108 to 120 in., excl.		120 to 132 in., excl.		132 in. or over.			
	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.		
Under 5	5	3	5.5	3	6	3	7	3	...	...	...	...	...	...	...	...	...	...			Under 5
5 to 7.5 excl.	4.5	3	5	3	5.5	3	6	3	...	...	...	...	...	...	...	...	...	...			5 to 7.5 excl.
7.5 " 10 "	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	...	...	...	...			7.5 " 10 "
10 " 12.5 "	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	9	3			10 " 12.5 "
12.5 " 15 "	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3			12.5 " 15 "
15 " 17.5 "	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3			15 " 17.5 "
17.5 " 20 "	2.5	2	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3			17.5 " 20 "
20 " 25 "	2	2	2.5	2	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3			20 " 25 "
25 " 30 "	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	4.5	3	5	3			25 " 30 "
30 " 40 "	2	2	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	4.5	3			30 " 40 "
40 or over	2	2	2	2	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3			40 or over

NOTE.—The weight per square foot of individual plates shall not vary from the ordered weight by more than $1\frac{1}{3}$ times the amount given in this table.

TABLE II.—PERMISSIBLE OVERWEIGHTS OF PLATES ORDERED TO THICKNESS.

ORDERED THICKNESS, IN.	PERMISSIBLE EXCESS IN AVERAGE WEIGHTS PER SQUARE FOOT OF PLATES FOR WIDTHS GIVEN, EXPRESSED IN PERCENTAGES OF NOMINAL WEIGHTS.									ORDERED THICKNESS, IN.
	Under 48 in.	48 to 60 in., excl.	60 to 72 in., excl.	72 to 84 in., excl.	84 to 96 in., excl.	96 to 108 in., excl.	108 to 120 in., excl.	120 to 132 in., excl.	132 in. or over.	
Under 1/8	9	10	12	14	..	..	..	..	..	Under 1/8
1/8 to 3/16 excl.	8	9	10	12	..	..	..	..	..	1/8 to 3/16 excl.
3/16 " 1/4 "	7	8	9	10	12	..	..	..	..	3/16 " 1/4 "
1/4 " 5/16 "	6	7	8	9	10	12	14	16	19	1/4 " 5/16 "
5/16 " 3/8 "	5	6	7	8	9	10	12	14	17	5/16 " 3/8 "
3/8 " 7/16 "	4.5	5	6	7	8	9	10	12	15	3/8 " 7/16 "
7/16 " 1/2 "	4	4.5	5	6	7	8	9	10	13	7/16 " 1/2 "
1/2 " 5/8 "	3.5	4	4.5	5	6	7	8	9	11	1/2 " 5/8 "
5/8 " 3/4 "	3	3.5	4	4.5	5	6	7	8	9	5/8 " 3/4 "
3/4 " 1 "	2.5	3	3.5	4	4.5	5	6	7	8	3/4 " 1 "
1 or over	2.5	2.5	3	3.5	4	4.5	5	6	7	1 or over

of the fracture is outside the middle third of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

PERMISSIBLE VARIATIONS IN WEIGHT AND THICKNESS

Permissible Variations.

10. The cross-section or weight of each piece of steel shall not vary more than 2.5 per cent from that specified; except in the case of sheared plates, which shall be covered by the following permissible variations. One cubic inch of rolled steel is assumed to weigh 0.2833 lb.

(*a*) *When Ordered to Weight per Square Foot:* The weight of each lot[1] in each shipment shall not vary from the weight ordered more than the amount given in Table I.

(*b*) *When Ordered to Thickness:* The thickness of each plate shall not vary more than 0.01 in. under that ordered.

The overweight of each lot[1] in each shipment shall not exceed the amount given in Table II.

FINISH

Finish.

11. The finished material shall be free from injurious defects and shall have a workmanlike finish.

MARKING

Marking.

12. The name or brand of the manufacturer and the melt number shall be legibly rolled or stamped on all finished material. The melt number shall be legibly stamped on each test specimen.

INSPECTION AND REJECTION

Inspection.

13. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

[1] The term "lot" as applied to Table I means all of the plates of each group width and group weight; as applied to Table II it means all of the plates of each group width and group thickness.

Rejection.

14. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 4 shall be reported within five working days from the receipt of samples.

(*b*) Material which shows injurious defects subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

Rehearing.

15. Samples tested in accordance with Section 4, which represent rejected material, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

STANDARD SPECIFICATIONS
FOR
RIVET STEEL FOR SHIPS[1]

Serial Designation: A 13 – 24

These specifications are issued under the fixed designation A 13; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ADOPTED, 1901; REVISED, 1909, 1912, 1913, 1914, 1924.

A. Requirements for Rolled Bars.

MANUFACTURE

1. The steel shall be made by the open-hearth process. **Process.**

CHEMICAL PROPERTIES AND TESTS

2. The steel shall conform to the following requirements as to chemical composition: **Chemical Composition.**

Phosphorous	Acid	not over 0.06	per cent
	Basic	" " 0.04	"
Sulfur		" " 0.045	"

3. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus and sulfur. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 2. **Ladle Analyses.**

4. Analyses may be made by the purchaser from finished bars representing each melt. The phosphorus and sulfur content thus determined shall not exceed that specified in Section 2 by more than 25 per cent. **Check Analyses.**

PHYSICAL PROPERTIES AND TESTS

5. (*a*) The bars shall conform to the following requirements as to tensile properties: **Tension Tests.**

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

Tensile strength, lb. per sq. in.	55 000 – 65 000
Yield point, min., " "	0.5 tens. str.
Elongation in 8 in., min., per cent	1 500 000
(See Section 6.)	Tens. str.

(*b*) The yield point shall be determined by the drop of the beam of the testing machine.

Modifications in Elongation.

6. For bars over $\frac{3}{4}$ in. in diameter, a deduction from the percentage of elongation specified in Section 5 (*a*) of 0.25 per cent shall be made for each increase of $\frac{1}{32}$ in. of the specified diameter above $\frac{3}{4}$ in.

Bend Tests.

7. The test specimen shall bend cold through 180 deg. flat on itself without cracking on the outside of the bent portion.

Test Specimens.

8. (*a*) Test specimens shall be of the full diameter of bars as rolled.

(*b*) Tension and bend test specimens for rivet bars which have been cold-drawn shall be normalized before testing.

Number of Tests.

9. (*a*) Two tension and two bend tests shall be made from each melt, each of which shall conform to the requirements specified; except that if bars from one melt differ $\frac{3}{8}$ in. or more in diameter, one tension and one bend test shall be made from both the greatest and the least diameters rolled.

(*b*) If any test specimen develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 5 (*a*) and any part of the fracture is outside the middle third of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

PERMISSIBLE VARIATIONS IN DIAMETER

Permissible Variations.

10. The diameter of bars 1 in. or under in diameter shall not vary more than 0.01 in. from that specified; the diameter of bars over 1 in. to and including 2 in. in diameter shall not vary more than $\frac{1}{64}$ in. under nor more than $\frac{1}{32}$ in. over that specified.

FINISH

Finish.

11. The finished bars shall be free from injurious defects and shall have a workmanlike finish.

MARKING

Marking.

12. Rivet bars shall, when loaded for shipment, be properly separated and marked with the name or brand of the manu-

facturer and the melt number for identification. The melt number shall be legibly marked on each test specimen.

INSPECTION AND REJECTION

Inspection. 13. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the bars ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the bars are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection. 14. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 4 shall be reported within five working days from the receipt of samples.

(*b*) Bars which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

Rehearing. 15. Samples tested in accordance with Section 4, which represent rejected bars, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

B. Requirements for Rivets.

PHYSICAL PROPERTIES AND TESTS

Bend Tests. 16. The rivet shank shall bend cold through 180 deg. flat on itself, as shown in Fig. 1, without cracking on the outside of the bent portion.

Flattening Tests. 17. The rivet head shall flatten, while hot, to a diameter $2\frac{1}{2}$ times the diameter of the shank, as shown in Fig. 2, without cracking at the edges.

Number of Tests. 18. Three bend and three flattening tests shall be made from each size in each lot of rivets offered for inspection, each of which shall conform to the requirements specified.

WORKMANSHIP AND FINISH

Workmanship and Finish. 19. The rivets shall be true to form and concentric, shall be made in a workmanlike manner and shall be free from injurious defects.

INSPECTION AND REJECTION

Inspection. 20. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the rivets ordered. The manufacturer shall afford the inspector, free of cost, all reasonable

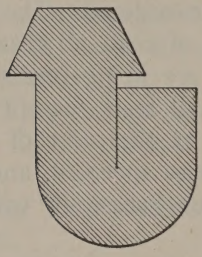


FIG. 1.

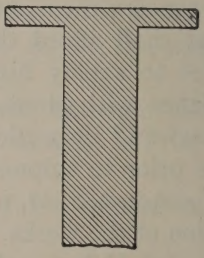


FIG. 2.

facilities to satisfy him that the rivets are being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection. 21. Rivets which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

STANDARD SPECIFICATIONS
FOR
BOILER AND FIREBOX STEEL FOR LOCOMOTIVES[1]

Serial Designation: A 30 – 24

These specifications are issued under the fixed designation A 30; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ADOPTED, 1901; REVISED, 1909, 1912, 1913, 1914, 1916, 1918, 1921, 1924.

1. These specifications cover two classes of steel for boilers for locomotives, namely: flange and firebox. **Scope.**

MANUFACTURE

2. The steel shall be made by the open-hearth process. **Process.**

CHEMICAL PROPERTIES AND TESTS

3. The steel shall conform to the following requirements as to chemical composition: **Chemical Composition.**

		Flange.	Firebox.
Carbon	for plates ¾ in. or under in thickness	....	not over 0.25 per cent
	for plates over ¾ in. in thickness	....	" " 0.30 "
Manganese	for plates ¾ in. or under in thickness	0.30 – 0.60	0.30 – 0.50 "
	for plates over ¾ in. in thickness	0.30 – 0.60	0.30 – 0.60 "
Phosphorus	Acid	not over 0.05	not over 0.04 "
	Basic	" " 0.04	" " 0.035 "
Sulfur		" " 0.05	" " 0.04 "

4. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements specified in Section 3. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 3. **Ladle Analyses.**

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

Check Analyses.

5. An analysis may be made by the purchaser from a broken tension test specimen representing each plate as rolled. The chemical composition thus determined shall conform to the requirements specified in Section 3.

PHYSICAL PROPERTIES AND TESTS

Tension Tests.

6. (*a*) The material shall conform to the following requirements as to tensile properties:

	Flange.	Firebox.
Tensile strength, lb. per sq. in.....	55 000 – 65 000	52 000 – 62 000
Yield point, min., " "	0.5 tens. str.	0.5 tens. str.
Elongation in 8 in., min., per cent.. (See Section 7)	$\frac{1\,500\,000}{\text{Tens. str.}}$	$\frac{1\,550\,000}{\text{Tens. str.}}$

(*b*) The yield point shall be determined by the drop of the beam of the testing machine.

Modifications in Elongation.

7. (*a*) For material over $\frac{3}{4}$ in. in thickness, a deduction from the percentages of elongation specified in Section 6 (*a*) of 0.125 per cent shall be made for each increase of $\frac{1}{32}$ in. of the specified thickness above $\frac{3}{4}$ in.

(*b*) For material $\frac{1}{4}$ in. or under in thickness, the elongation shall be measured on a gage length of 24 times the thickness of the specimen.

Bend Tests.

8. The test specimen shall bend cold through 180 deg. without cracking on the outside of the bent portion, as follows: For material 1 in. or under in thickness, around a pin the diameter of which is equal to the thickness of the specimen; and for material over 1 in. in thickness, around a pin the diameter of which is equal to twice the thickness of the specimen.

Homogeneity Tests.

9. For firebox steel, a sample taken from a broken tension test specimen shall not show any single seam or cavity more than $\frac{1}{4}$ in. long, in either of the three fractures obtained in the test for homogeneity, which shall be made as follows:

The specimen shall be either nicked with a chisel or grooved on a machine, transversely, about $\frac{1}{16}$ in. deep, in three places about 2 in. apart. The first groove shall be made 2 in. from the square end; each succeeding groove shall be made on the opposite side from the preceding one. The specimen shall then be firmly held in a vise, with the first groove about $\frac{1}{4}$ in. above the jaws, and the projecting end broken off by light blows of a hammer, the bending being away from the groove. The specimen shall be broken at the other two grooves in the same manner. The object

of this test is to open and render visible to the eye any seams due to failure to weld up or to interposed foreign matter, or any cavities due to gas bubbles in the ingot. One side of each fracture shall be examined and the lengths of the seams and cavities determined, a pocket lens being used if necessary.

Test Specimens.

10. (*a*) Tension test specimens shall be taken longitudinally from the bottom of the finished rolled material, and bend test specimens shall be taken transversely from the middle of the top of the finished rolled material. The longitudinal test specimens shall be taken in the direction of the longitudinal axis of the ingot, and the transverse test specimens at right angles to that axis.

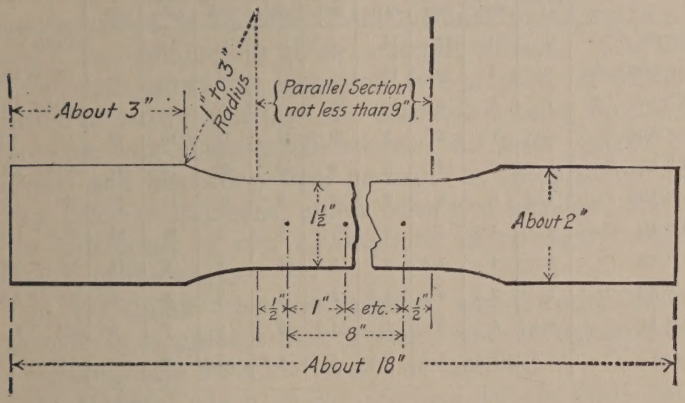


FIG. 1.

(*b*) Tension and bend test specimens shall be of the full thickness of material as rolled, and shall be machined to the form and dimensions shown in Fig. 1; except that bend test specimens may be machined with both edges parallel.

Number of Tests.

11. (*a*) One tension and one bend test shall be made from each plate as rolled.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 6 (*a*) and any part of the fracture is outside the middle third of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

PERMISSIBLE VARIATIONS IN WEIGHT AND THICKNESS

Permissible Variations.

12. The thickness of each plate shall not vary more than 0.01 in. under that ordered.

The overweight of each lot[1] in each shipment shall not exceed the amount given in Table I. One cubic inch of rolled steel is assumed to weigh 0.2833 lb.

TABLE I.—PERMISSIBLE OVERWEIGHTS OF PLATES ORDERED TO THICKNESS.

ORDERED THICKNESS, IN.	PERMISSIBLE EXCESS IN AVERAGE WEIGHTS PER SQUARE FOOT OF PLATES FOR WIDTHS GIVEN, EXPRESSED IN PERCENTAGES OF NOMINAL WEIGHTS.									ORDERED THICKNESS, IN.
	Under 48 in.	48 to 60 in., excl.	60 to 72 in., excl.	72 to 84 in., excl.	84 to 96 in., excl.	96 to 108 in., excl.	108 to 120 in., excl.	120 to 132 in., excl.	132 in. or over.	
Under 1/8	9	10	12	14	..	..	..	..	..	Under 1/8
1/8 to 3/16 excl.	8	9	10	12	..	..	..	..	..	1/8 to 3/16 excl.
3/16 " 1/4 "	7	8	9	10	12	..	..	..	..	3/16 " 1/4 "
1/4 " 5/16 "	6	7	8	9	10	12	14	16	19	1/4 " 5/16 "
5/16 " 3/8 "	5	6	7	8	9	10	12	14	17	5/16 " 3/8 "
3/8 " 7/16 "	4.5	5	6	7	8	9	10	12	15	3/8 " 7/16 "
7/16 " 1/2 "	4	4.5	5	6	7	8	9	10	13	7/16 " 1/2 "
1/2 " 5/8 "	3.5	4	4.5	5	6	7	8	9	11	1/2 " 5/8 "
5/8 " 3/4 "	3	3.5	4	4.5	5	6	7	8	9	5/8 " 3 4 "
3/4 " 1 "	2.5	3	3.5	4	4.5	5	6	7	8	3/4 " 1
1 or over	2.5	2.5	3	3.5	4	4.5	5	6	7	1 or over

FINISH

Finish.

13. The finished material shall be free from injurious defects and shall have a workmanlike finish.

MARKING

Marking.

14. (*a*) The name or brand of the manufacturer, the manufacturer's test identification number, class and lowest tensile strength specified shall be legibly stamped on each finished plate in two places not less than 12 in. from the edges and on each butt strap near the center line not less than 12 in. from each end. The manufacturer's test identification number shall be legibly stamped on each test specimen.

(*b*) When specified on the order, plates shall be match-marked as defined in Paragraph (*c*) so that the test specimens representing them may be identified. When more than one plate is sheared from a single slab or ingot, each shall be match-

[1] The term "lot" applied to Table I means all of the plates of each group width and group thickness.

marked so that they may all be identified with the test specimen representing them.

(*c*) Each match mark shall consist of two over-lapping circles each not less than 1½ in. in diameter, placed upon the shear lines, and made by separate impressions of a single-circle steel die.

(*d*) Match-marked coupons shall match with the sheets represented and only those which match properly shall be accepted.

INSPECTION AND REJECTION

Inspection.

15. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection.

16. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 5 shall be reported within five working days from the receipt of samples.

(*b*) Material which shows injurious defects subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

Rehearing.

17. Samples tested in accordance with Section 5, which represent rejected material, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

STANDARD SPECIFICATIONS
FOR
BOILER AND FIREBOX STEEL FOR STATIONARY SERVICE[1]

Serial Designation: A 70 – 27

These specifications are issued under the fixed designation A 70; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1916; ADOPTED IN AMENDED FORM, 1924; REVISED, 1927.

Scope.

1. These specifications cover two classes of steel for boilers for stationary service, namely: flange and firebox.

MANUFACTURE

Process.

2. The steel shall be made by the open-hearth process.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

3. The steel shall conform to the following requirements as to chemical composition:

		Flange	Firebox
Carbon	For plates ¾ in. or under in thickness	.....	not over 0.25 per cent
	For plates over ¾ in. in thickness	.....	" " 0.30 "
Manganese	For plates ¾ in. or under in thickness	0.30 – 0.60	0.30 – 0.50 "
	For plates over ¾ in. in thickness	0.30 – 0.60	0.30 – 0.60 "
Phosphorus	Acid	not over 0.05	not over 0.04
	Basic	" " 0.04	" " 0.035 "
Sulfur		" " 0.05	" " 0.04 "

Ladle Analyses.

4. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements specified in Section 3. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 3.

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

5. An analysis may be made by the purchaser from a broken tension test specimen representing each plate as rolled. The chemical composition thus determined shall conform to the requirements specified in Section 3. Check Analyses.

PHYSICAL PROPERTIES AND TESTS

6. (*a*) The material shall conform to the following requirements as to tensile properties: Tension Tests.

	Flange	Firebox
Tensile strength, lb. per sq. in.....	55 000 – 65 000	55 000 – 65 000
Yield point, min., per sq. in.....	0.5 tens. str.	0.5 tens. str.
Elongation in 8 in., min., per cent....	1 500 000 / Tens. str.	1 550 000 / Tens. str.

(*b*) Tensile strength only need be determined on the test specimen taken longitudinally from the top of firebox plates, and it shall not exceed 70,000 lb. per sq. in.

(*c*) Should the above rule for minimum allowable elongation give a value of less than 25 per cent for firebox steel, the minimum allowable elongation shall be 25 per cent, subject to the modifications of Section 7.

(*d*) The yield point shall be determined by the drop of the beam of the testing machine.

7. (*a*) For material over $\frac{3}{4}$ in. in thickness, a deduction from the percentage of elongation specified in Section 6 (*a*) of 0.125 per cent shall be made for each increase of $\frac{1}{32}$ in. of the specified thickness above $\frac{3}{4}$ in., to a minimum of 20 per cent. Modifications in Elongation.

(*b*) For material $\frac{1}{4}$ in. or under in thickness, the elongation shall be measured on a gage length of 24 times the thickness of the specimen.

8. (*a*) The test specimen shall stand being bent cold through 180 deg. without cracking on the outside of the bent portion, as follows: For material 1 in. or under in thickness, around a pin the diameter of which is equal to the thickness of the specimen; and for material over 1 in. in thickness, around a pin the diameter of which is equal to twice the thickness of the specimen. Bend Tests.

(*b*) *Bend Test for Universal Edge Rolled Plates When Permitted for Double-Butt-Strap Construction.*—The bend test specimen shall stand being bent cold through 180 deg. without cracking on the outside of the bent portion, as follows: For material 1 in. or under in thickness, around a pin the diameter of which is equal to $1\frac{1}{2}$ times the thickness of the specimen; and for material over 1 in. in thickness, around a pin the diameter of which is equal to three times the thickness of the specimen.

Homogeneity Tests.

9. For firebox steel, a sample taken from a broken tension test specimen shall not show any single seam or cavity more than $\frac{1}{4}$ in. in length, in either of the three fractures obtained in the test for homogeneity, which shall be made as follows:

The specimen shall be either nicked with a chisel or grooved on a machine, transversely, about $\frac{1}{16}$ in. deep, in three places about 2 in. apart. The first groove shall be made 2 in. from the square end; each succeeding groove shall be made on the opposite side from the preceding one. The specimen shall then be firmly held in a vise, with the first groove about $\frac{1}{4}$ in. above the jaws, and the projecting end broken off by light blows of a hammer, the bending being away from the groove. The specimen shall be broken at the other two

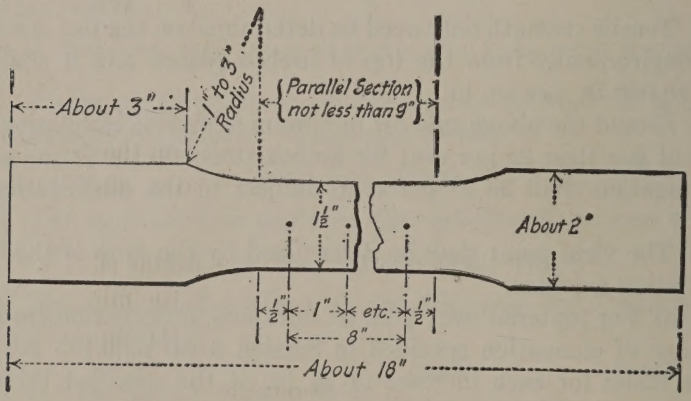


FIG. 1.

grooves in the same manner. The object of this test is to open and render visible to the eye any seams due to failure to weld up or to interposed foreign matter, or any cavities due to gas bubbles in the ingot. One side of each fracture shall be examined and the lengths of the seams and cavities determined, a pocket lens being used if necessary.

Test Specimens.

10. (*a*) Tension test specimens shall be taken longitudinally from the top and bottom corners of the finished rolled firebox material and from the bottom only of flange material. Bend test specimens shall be taken transversely from the middle of the top of the finished rolled material. The longitudinal test specimen shall be taken in the direction of the longitudinal axis of the ingot, and the transverse test specimen at right angles to that axis.

(*b*) Tension and bend test specimens shall be of the full thickness of material as rolled, and shall be machined to the form and dimen-

sions shown in Fig. 1; except that bend test specimens may be machined with both edges parallel.

Number of Tests.

11. (*a*) Two tension and one bend test shall be made from each firebox steel plate as rolled. One tension and one bend test shall be made from each flange steel plate as rolled.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 6 (*a*) and any part of the fracture is outside the middle third of the gage length, as indicated by scribe

TABLE I.—PERMISSIBLE OVERWEIGHTS OF PLATES ORDERED TO THICKNESS.

Ordered Thickness, in.	Permissible Excess in Average Weights per Square Foot of Plates for Widths Given, Expressed in Percentages of Nominal Weights.									Ordered Thickness, in.
	Under 48 in.	48 to 60 in., excl.	60 to 72 in., excl.	72 to 84 in., excl.	84 to 96 in., excl.	96 to 108 in., excl.	108 to 120 in., excl.	120 to 132 in., excl.	132 in. or over	
Under $\frac{1}{8}$	9	10	12	14	..	..	..	..	..	Under $\frac{1}{8}$
$\frac{1}{8}$ to $\frac{3}{16}$ excl.	8	9	10	12	..	..	..	..	..	$\frac{1}{8}$ to $\frac{3}{16}$ excl.
$\frac{3}{16}$ " $\frac{1}{4}$ "	7	8	9	10	12	..	..	..	..	$\frac{3}{16}$ " $\frac{1}{4}$ "
$\frac{1}{4}$ " $\frac{5}{16}$ "	6	7	8	9	10	12	14	16	19	$\frac{1}{4}$ " $\frac{5}{16}$ "
$\frac{5}{16}$ " $\frac{3}{8}$ "	5	6	7	8	9	10	12	14	17	$\frac{5}{16}$ " $\frac{3}{8}$ "
$\frac{3}{8}$ " $\frac{7}{16}$ "	4.5	5	6	7	8	9	10	12	15	$\frac{3}{8}$ " $\frac{7}{16}$ "
$\frac{7}{16}$ " $\frac{1}{2}$ "	4	4.5	5	6	7	8	9	10	13	$\frac{7}{16}$ " $\frac{1}{2}$ "
$\frac{1}{2}$ " $\frac{5}{8}$ "	3.5	4	4.5	5	6	7	8	9	11	$\frac{1}{2}$ " $\frac{5}{8}$ "
$\frac{5}{8}$ " $\frac{3}{4}$ "	3	3.5	4	4.5	5	6	7	8	9	$\frac{5}{8}$ " $\frac{3}{4}$ "
$\frac{3}{4}$ " 1 "	2.5	3	3.5	4	4.5	5	6	7	8	$\frac{3}{4}$ " 1 "
1 or over	2.5	2.5	3	3.5	4	4.5	5	6	7	1 or over

scratches marked on the specimen before testing, a retest shall be allowed.

PERMISSIBLE VARIATIONS IN WEIGHT AND THICKNESS

Permissible Variations.

12. The thickness of each plate shall not vary more than 0.01 in. under that ordered.

The overweight of each lot[1] in each shipment shall not exceed the amount given in Table I. One cubic inch of rolled steel is assumed to weigh 0.2833 lb.

FINISH

Finish.

13. The finished material shall be free from injurious defects and shall have a workmanlike finish.

[1] The term "lot" applied to Table I means all of the plates of each group width and group thickness.

MARKING

Marking.

14. (*a*) The name or brand of the manufacturer, the manufacturer's test identification number, class and lowest tensile strength specified shall be legibly stamped on each finished plate in two places not less than 12 in. from the edges and on each butt strap near the center line not less than 12 in. from each end. The manufacturer's test identification number shall be legibly stamped on each test specimen.

(*b*) When specified on the order, plates shall be match-marked as defined in Paragraph (*c*) so that the test specimens representing them may be identified. When more than one plate is sheared from a single slab or ingot, each shall be match-marked so that they may all be identified with the test specimens representing them.

(*c*) Each match mark shall consist of two over-lapping circles each not less than $1\frac{1}{2}$ in. in diameter, placed upon the shear lines, and made by separate impressions of a single-circle steel die.

(*d*) Match-marked coupons shall match with the sheets represented and only those which match properly shall be accepted.

INSPECTION AND REJECTION

Inspection.

15. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection.

16. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 5, shall be reported within five working days from the receipt of samples.

(*b*) Material which shows injurious defects subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

Rehearing.

17. Samples tested in accordance with Section 5, which represent rejected material, shall be preserved for two weeks from date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

STANDARD SPECIFICATIONS
FOR
BOILER RIVET STEEL[1]
Serial Designation: A 31 – 24

These specifications are issued under the fixed designation A 31; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ADOPTED, 1901; REVISED, 1909, 1912, 1913, 1914, 1921, 1924.

A. Requirements for Rolled Bars

MANUFACTURE

1. The steel shall be made by the open-hearth process. Process.

CHEMICAL PROPERTIES AND TESTS

2. The steel shall conform to the following requirements as to chemical composition: Chemical Composition.

Manganese	0.30 – 0.50 per cent
Phosphorus	not over 0.04 "
Sulfur	" " 0.045 "

3. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus and sulfur. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 2. Ladle Analyses.

4. Analyses may be made by the purchaser from finished bars representing each melt. The chemical composition thus determined shall conform to the requirements specified in Section 2. Check Analyses.

PHYSICAL PROPERTIES AND TESTS

5. (*a*) The bars shall conform to the following requirements as to tensile properties: Tension Tests.

Tensile strength, lb. per sq. in	45 000 – 55 000
Yield point, min., lb. per sq. in	0.5 tens. str.
Elongation in 8 in., min., per cent	$\frac{1\,500\,000}{\text{Tens. str.}}$

but need not exceed 30 per cent

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

(*b*) The yield point shall be determined by the drop of the beam of the testing machine.

Bend Tests.

6. (*a*) *Cold-bend Tests.*—The test specimen shall stand being bent cold through 180 deg. flat on itself without cracking on the outside of the bent portion.

(*b*) *Quench-bend Tests.*—The test specimen, when heated to a light cherry red as seen in the dark (not less than 1200° F.), and quenched at once in water the temperature of which is between 80 and 90° F., shall stand being bent through 180 deg. flat on itself without cracking on the outside of the bent portion.

Test Specimens.

7. (*a*) Test specimens shall be of the full diameter of bars as rolled.

(*b*) Tension and bend test specimens for rivet bars which have been cold-drawn shall be normalized before testing.

Number of Tests.

8. (*a*) Two tension, two cold-bend, and two quench-bend tests shall be made from each melt, each of which shall conform to the requirements specified.

(*b*) If any test specimen develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 5 (*a*) and any part of the fracture is outside the middle third of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

PERMISSIBLE VARIATIONS IN DIAMETER

Permissible Variations.

9. The diameter of hot-finished rivet bars shall not vary from that specified by more than the amount given in the following table:

Diameter, in.	Variations in Diameter, in. Under	Over	Out of Round, in.
Up to ½, inclusive	0.007	0.007	0.010
Over ½ to 1, inclusive	0.010	0.010	0.013
Over 1 to 1¼, inclusive	0.012	0.012	0.016
Over 1¼ to 1½, inclusive	0.015	0.015	0.021
Over 1½ to 2, inclusive	0.022	0.022	0.023

FINISH

Finish.

10. The finished bars shall be free from injurious defects and shall have a workmanlike finish.

MARKING

Marking.

11. Rivet bars shall, when loaded for shipment, be properly separated and marked with the name or brand of the manufacturer and the melt number for identification. The melt number shall be legibly marked on each test specimen.

INSPECTION AND REJECTION

12. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the bars ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the bars are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works. Inspection.

13. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 4 shall be reported within five working days from the receipt of samples. Rejection.

(*b*) Bars which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

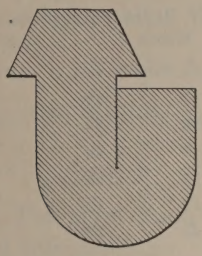


FIG. 1.

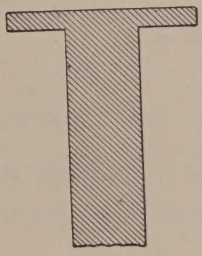


FIG. 2.

14. Samples tested in accordance with Section 4, which represent rejected bars, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time. Rehearing.

B. Requirements for Rivets

PHYSICAL PROPERTIES AND TESTS

15. The rivet shank shall stand being bent cold through 180 deg. flat on itself, as shown in Fig. 1, without cracking on the outside of the bent portion. Bend Tests.

16. The rivet head shall flatten, while hot, to a diameter $2\frac{1}{2}$ times the diameter of the shank, as shown in Fig. 2, without cracking at the edges. Flattening Tests.

17. Three bend and three flattening tests shall be made from each size in each lot of rivets offered for inspection, each of which shall conform to the requirements specified. Number of Tests.

PERMISSIBLE VARIATIONS IN DIAMETER

Permissible Variations.

18. The diameter of finished rivets, measured cold, shall not vary from that specified more than the amounts given in the following table:

Diameter, in.	Variations in Diameter, in. Snap Gage Measurement	Ring Gage Measurement
Up to $\frac{1}{2}$, inclusive	0.022 under	0.020 over
Over $\frac{1}{2}$ to 1, inclusive	0.025 "	0.030 "
Over 1 to $1\frac{1}{4}$, inclusive	0.027 "	0.035 "
Over $1\frac{1}{4}$ to $1\frac{1}{2}$, inclusive	0.030 "	0.040 "
Over $1\frac{1}{2}$ to 2, inclusive	0.037 "	0.040 "

Snap gage measurement shall be made at the point of minimum diameter, but it is not required that the rivet shall turn completely in the gage. Measurements of the maximum tolerance shall be made with a ring gage, all rivets to slip full to the head in the gage of the required size for the various diameters.

19. The dimensions of the rivet head shall not vary from that specified more than the amounts given in the following table:

Ordered Diameter of Rivets, in.	Head Tolerances, in. Width	Height
$\frac{1}{2}$	plus $\frac{1}{16}$ minus $\frac{1}{32}$	plus $\frac{1}{32}$
$\frac{9}{16}$	" $\frac{1}{16}$ " $\frac{1}{32}$	" $\frac{1}{32}$
$\frac{5}{8}$	" $\frac{1}{16}$ " $\frac{1}{32}$	" $\frac{1}{32}$
$\frac{11}{16}$	" $\frac{1}{16}$ " $\frac{1}{32}$	" $\frac{1}{32}$
$\frac{3}{4}$	" $\frac{5}{64}$ " $\frac{1}{32}$	" $\frac{1}{32}$
$\frac{7}{8}$	" $\frac{5}{64}$ " $\frac{1}{32}$	" $\frac{1}{32}$
1	" $\frac{5}{64}$ " $\frac{1}{32}$	" $\frac{1}{32}$

WORKMANSHIP AND FINISH

Workmanship and Finish.

20. The rivets shall be true to form and concentric, shall be made in a workmanlike manner, and shall be free from injurious defects.

INSPECTION AND REJECTION

Inspection.

21. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the rivets ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the rivets are being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection.

22. Rivets which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

STANDARD SPECIFICATIONS

FOR

STEEL PLATES OF STRUCTURAL QUALITY FOR FORGE WELDING[1]

Serial Designation: A 78 – 27

These specifications are issued under the fixed designation A 78; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1919; ADOPTED IN AMENDED FORM, 1927.

Scope. 1. These specifications cover steel plates of structural quality suitable for forge welding without the use of fluxes where the weld is not reinforced.

MANUFACTURE

Process. 2. The steel shall be made by the open-hearth process.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition. 3. (*a*) The steel shall conform to the following requirements as to chemical composition:

	Grade A.	Grade B.
Carbon, for plates ¾ in. or under in thickness	not over 0.15 per cent	not over 0.20 per cent
Carbon, for plates over ¾ in. in thickness	" 0.17 "	" 0.22 "
Manganese	0.35 to 0.60 "	0.35 to 0.60 "
Phosphorus	not over 0.06 "	not over 0.06 "
Sulfur	" 0.05 "	" 0.05 "

(*b*) The composition of the steel should preferably be free from silicon, nickel or chromium. Where these elements are present the maximum quantity of any one shall not exceed 0.05 per cent.

Ladle Analyses 4. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus and sulfur. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 3.

Check Analyses.

5. An analysis may be made by the purchaser from a broken tension test specimen representing each melt. The chemical composition thus determined shall conform to the requirements specified in Section 3.

PHYSICAL PROPERTIES AND TESTS.

Tension Tests.

6. (*a*) The material shall conform to the following minimum requirements as to tensile properties:

	GRADE A.	GRADE B.
Tensile strength, lb. per sq. in.....	45,000	50,000
Yield point, lb. per sq. in.....	0.5 tens. str.	0.5 tens. str.
but in no case less than.....	24,000	27,000
Elongation in 8 in., per cent.....	28	25

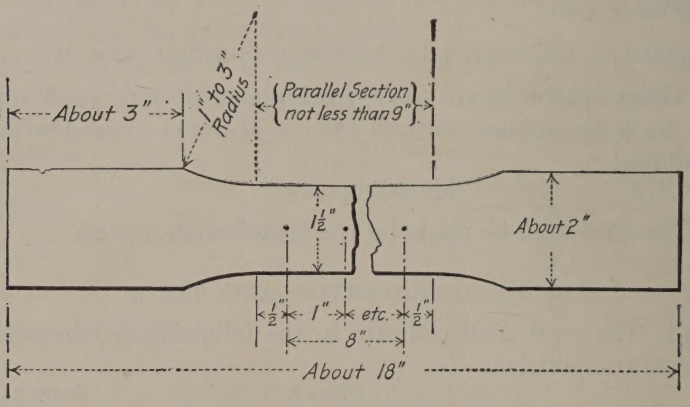


FIG. 1.

(*b*) The yield point shall be determined by the drop of the beam of the testing machine.

Modifications in Elongation.

7. (*a*) For material over $\frac{3}{4}$ in. in thickness, a deduction from the percentages of elongation specified in Section 6 (*a*) of 0.25 per cent shall be made for each increase of $\frac{1}{32}$ in. of the specified thickness above $\frac{3}{4}$ in., to a minimum of 20 per cent.

(*b*) For material under $\frac{5}{16}$ in. in thickness a deduction from the percentages of elongation specified in Section 6 (*a*) of 1.25 per cent shall be made for each decrease of $\frac{1}{32}$ in. of the specified thickness below $\frac{5}{16}$ in.

Bend Tests.

8. The test specimen shall stand being bent cold through 180 deg. flat on itself without cracking on the outside of the bent portion.

Test Specimens.

9. (*a*) Test specimens shall be prepared for testing from the material in its rolled condition.

(*b*) Test specimens shall be taken longitudinally and, except as specified in Paragraph (*c*), shall be of the full thickness of material as rolled. They may be machined to the form and dimensions shown in Fig. 1, or with both edges parallel.

(*c*) Test specimens for plates over $1\frac{1}{2}$ in. in thickness may be machined to a thickness or diameter of at least $\frac{3}{4}$ in. for a length of at least 9 in.

(*d*) The machined sides of rectangular bend test specimens may have the corners rounded to a radius not over $\frac{1}{16}$ in.

Number of Tests.

10. (*a*) One tension and one bend test shall be made from each melt; except that if material from one melt differs $\frac{3}{8}$ in. or more in thickness, one tension and one bend test shall be made from both the thickest and the thinnest material rolled.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 6 (*a*) and any part of the fracture is outside the middle third of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

PERMISSIBLE VARIATIONS IN WEIGHT AND THICKNESS.

Permissible Variations.

11. The cross-section or weight of plates shall be covered by the following permissible variations. One cubic inch of rolled steel is assumed to weigh 0.2833 lb.

(*a*) *When Ordered to Weight per Square Foot:* The weight of each lot[1] in each shipment shall not vary from the weight ordered more than the amount given in Table I.

(*b*) *When Ordered to Thickness:* The thickness of each plate shall not vary more than 0.01 in. under that ordered.

The overweight of each lot[1] in each shipment shall not exceed the amount given in Table II.

FINISH.

Finish.

12. The finished material shall be free from injurious defects and shall have a workmanlike finish.

MARKING.

Marking.

13. The name or brand of the manufacturer and the melt number shall be legibly rolled or stamped on all finished material. The melt number shall be legibly marked, by stamping if practicable, on each test specimen.

[1] The term "lot" as applied to Table I means all of the plates of each group width and group weight; as applied to Table II, it means all of the plates of each group width and group thickness.

INSPECTION AND REJECTION.

Inspection.

14. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern

TABLE I.—PERMISSIBLE VARIATIONS OF PLATES ORDERED TO WEIGHT.

Ordered Weight, lb. per sq. ft.	Permissible Variations in Average Weights per Square Foot of Plates for Widths Given, Expressed in Percentages of Ordered Weights.																		Ordered Weight, lb. per sq. in.
	Under 48 in.		48 to 60 in., excl.		60 to 72 in., excl.		72 to 84 in., excl.		84 to 96 in., excl.		96 to 108 in., excl.		108 to 120 in., excl.		120 to 132 in., excl.		132 in. or over.		
	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	
Under 5	5	3	5.5	3	6	3	7	3	...	...	...	...	...	...	...	...	...	...	Under 5
5 to 7.5 excl.	4.5	3	5	3	5.5	3	6	3	...	...	...	...	...	...	...	...	...	...	5 to 7.5 excl.
7.5 " 10 "	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	...	...	...	...	7.5 " 10 "
10 " 12.5 "	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	9	3	10 " 12.5 "
12.5 " 15 "	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	12.5 " 15 "
15 " 17.5 "	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	15 " 17.5 "
17.5 " 20 "	2.5	2	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	17.5 " 20 "
20 " 25 "	2	2	2.5	2	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	20 " 25 "
25 " 30 "	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	4.5	3	5	3	25 " 30 "
30 " 40 "	2	2	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	4.5	3	30 " 40 "
40 or over	2	2	2	2	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	40 or over

NOTE.—The weight per square foot of individual plates shall not vary from the ordered weight by more than $1\frac{1}{3}$ times the amount given in this table.

TABLE II.—PERMISSIBLE OVERWEIGHTS OF PLATES ORDERED TO THICKNESS.

Ordered Thickness, in.	Permissible Excess in Average Weights per Square Foot of Plates for Widths Given, Expressed in Percentages of Nominal Weights.									Ordered Thickness, in.
	Under 48 in.	48 to 60 in., excl.	60 to 72 in., excl.	72 to 84 in., excl.	84 to 96 in., excl.	96 to 108 in., excl.	108 to 120 in., excl.	120 to 132 in., excl.	132 in. or over.	
Under $\frac{1}{8}$	9	10	12	14	..	..	..	..	..	Under $\frac{1}{8}$
$\frac{1}{8}$ to $\frac{3}{16}$ excl.	8	9	10	12	..	..	..	..	..	$\frac{1}{8}$ to $\frac{3}{16}$ excl.
$\frac{3}{16}$ " $\frac{1}{4}$ "	7	8	9	10	12	..	..	..	..	$\frac{3}{16}$ " $\frac{1}{4}$ "
$\frac{1}{4}$ " $\frac{5}{16}$ "	6	7	8	9	10	12	14	16	19	$\frac{1}{4}$ " $\frac{5}{16}$ "
$\frac{5}{16}$ " $\frac{3}{8}$ "	5	6	7	8	9	10	12	14	17	$\frac{5}{16}$ " $\frac{3}{8}$ "
$\frac{3}{8}$ " $\frac{7}{16}$ "	4.5	5	6	7	8	9	10	12	15	$\frac{3}{8}$ " $\frac{7}{16}$ "
$\frac{7}{16}$ " $\frac{1}{2}$ "	4	4.5	5	6	7	8	9	10	13	$\frac{7}{16}$ " $\frac{1}{2}$ "
$\frac{1}{2}$ " $\frac{5}{8}$ "	3.5	4	4.5	5	6	7	8	9	11	$\frac{1}{2}$ " $\frac{5}{8}$ "
$\frac{5}{8}$ " $\frac{3}{4}$ "	3	3.5	4	4.5	5	6	7	8	9	$\frac{5}{8}$ " $\frac{3}{4}$ "
$\frac{3}{4}$ " 1 "	2.5	3	3.5	4	4.5	5	6	7	8	$\frac{3}{4}$ " 1 "
1 or over	2.5	2.5	3	3.5	4	4.5	5	6	7	1 or over

the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these

specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

15. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 5 shall be reported within five working days from the receipt of samples. Rejection.

(*b*) Material which shows injurious defects subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

16. Samples tested in accordance with Section 5, which represent rejected material, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests the manufacturer may make claim for a rehearing within that time, Rehearing.

STANDARD SPECIFICATIONS FOR STEEL PLATES OF FLANGE QUALITY FOR FORGE WELDING[1]

Serial Designation: A 89 – 27

These specifications are issued under the fixed designation A 89; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1923; ADOPTED IN AMENDED FORM, 1927.

Scope.

1. These specifications cover steel plates of flange quality suitable for forge welding without the use of fluxes where the weld is not reinforced.

MANUFACTURE

Process.

2. The steel shall be made by the open-hearth process.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

3. (*a*) The steel shall conform to the following requirements as to chemical composition:

		Grade A	Grade B
Carbon	for plates ¾ in. or under in thickness	not over 0.15 per cent	not over 0.20 per cent
	for plates over ¾ in. in thickness	" " 0.17 "	" " 0.22 "
Manganese		0.35 to 0.60 "	0.35 to 0.60 "
Phosphorus	Acid	not over 0.06 "	not over 0.06 "
	Basic	" " 0.04 "	" " 0.04 "
Sulfur		" " 0.05 "	" " 0.05 "

(*b*) The composition of the steel should preferably be free from silicon, nickel or chromium. Where these elements are present the maximum quantity of any one shall not exceed 0.05 per cent.

Ladle Analyses.

4. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus and sulfur. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 3.

Check Analyses.

5. An analysis may be made by the purchaser from a broken tension test specimen representing each plate as rolled. The chemical composition thus determined shall conform to the requirements specified in Section 3.

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

PHYSICAL PROPERTIES AND TESTS

6. (*a*) The material shall conform to the following minimum requirements as to tensile properties. **Tension Tests.**

	GRADE A.	GRADE B.
Tensile strength, lb. per sq. in.....	45,000	50,000
Yield point, lb. per sq. in.....	0.5 tens. str.	0.5 tens. str.
but in no case less than.....	24,000	27,000
Elongation in 8 in., per cent.....	30	27

(*b*) The yield point shall be determined by the drop of the beam of the testing machine.

7. (*a*) For material over $\frac{3}{4}$ in. in thickness, a deduction from the percentages of elongation specified in Section 6 (*a*) of 0.125 per cent shall be made for each increase of $\frac{1}{32}$ in. of the specified thickness above $\frac{3}{4}$ in. **Modifications in Elongation.**

(*b*) For material under $\frac{5}{16}$ in. in thickness, a deduction from the percentage of elongation in 8 in. specified in Section 6 (*a*) of 1.25 per cent shall be made for each decrease of $\frac{1}{32}$ in. of the specified thickness below $\frac{5}{16}$ in.

8. The test specimen shall stand being bent cold through 180 deg. without cracking on the outside of the bent portion, as follows: For material 1 in. or under in thickness, around a pin the diameter of which is equal to the thickness of the specimen; and for material over 1 in. in thickness, around a pin the diameter of which is equal to twice the thickness of the specimen. **Bend Tests.**

9. (*a*) Tension test specimens shall be taken longitudinally from the bottom of the finished rolled material, and bend test specimens shall be taken transversely from the middle of the top of the finished rolled material. The longitudinal test specimens shall be taken in the direction of the longitudinal axis of the ingot, and the transverse test specimens at right angles to that axis. **Test Specimens.**

(*b*) Tension and bend test specimens shall be of the full thickness of material as rolled, and shall be machined to the form and dimensions shown in Fig. 1; except that bend test specimens may be machined with both edges parallel.

(*c*) Test specimens for plates over $1\frac{1}{2}$ in. in thickness may be machined to a thickness or diameter of at least $\frac{3}{4}$ in. for a length of at least 9 in.

(*d*) The machined sides of rectangular bend test specimens may have the corners rounded to a radius not over $\frac{1}{16}$ in.

10. (*a*) One tension and one bend test shall be made from each plate as rolled. **Number of Tests.**

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 6 (*a*) and any part of the fracture is outside the middle third of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

PERMISSIBLE VARIATIONS IN WEIGHT AND THICKNESS

Permissible Variations.

11. The thickness of each plate shall not vary more than 0.01 in. under that ordered.

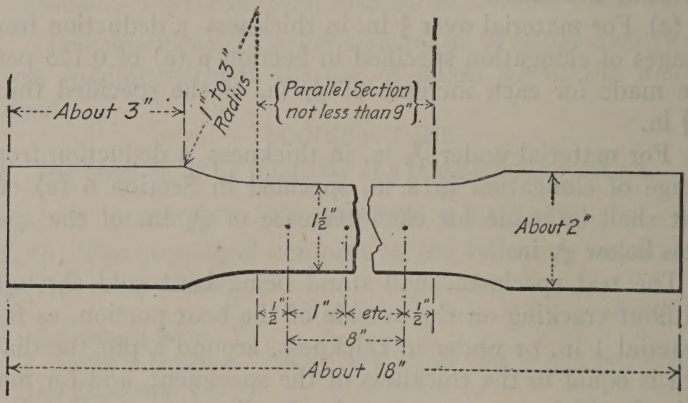


FIG. 1.

The overweight of each lot[1] in each shipment shall not exceed the amount given in Table I. One cubic inch of rolled steel is assumed to weigh 0.2833 lb.

FINISH

Finish.

12. The finished material shall be free from injurious defects and shall have a workmanlike finish.

MARKING

Marking.

13. (*a*) The name or brand of the manufacturer, melt or slab number, class, and lowest tensile strength for the grade specified in Section 6 (*a*) shall be legibly stamped on each plate. The melt or slab number shall be legibly stamped on each test specimen.

(*b*) When specified on the order, plates shall be match-marked as defined in Paragraph (*c*) so that the test specimens representing them may be identified. When more than one plate is sheared from a single slab or ingot, each shall be match-marked so that they may all be identified with the test specimen representing them.

[1] The term "lot" applied to Table I means all of the plates of each group width and group thickness.

(*c*) Each match mark shall consist of two over-lapping circles each not less than $1\frac{1}{2}$ in. in diameter, placed upon the shear lines, and made by separate impressions of a single-circle steel die.

(*d*) Match-marked coupons shall match with the sheets represented and only those which match properly shall be accepted.

INSPECTION AND REJECTION

Inspection.

14. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these

TABLE I.—PERMISSIBLE OVERWEIGHTS OF PLATES ORDERED TO THICKNESS.

Ordered Thickness, in.	Permissible Excess in Average Weights per Square Foot of Plates for Widths Given, Expressed in Percentages of Nominal Weights.									Ordered Thickness, in.
	Under 48 in.	48 to 60 in., excl.	60 to 72 in., excl.	72 to 84 in. excl.	84 to 96 in., excl.	96 to 108 in., excl.	108 to 120 in., excl.	120 to 132 in., excl.	132 in. or over	
Under $\frac{1}{8}$	9	10	12	14	..	..	..	..	..	Under $\frac{1}{8}$
$\frac{1}{8}$ to $\frac{3}{16}$ excl	8	9	10	12	..	..	..	..	..	$\frac{1}{8}$ to $\frac{3}{16}$ excl.
$\frac{3}{16}$ " $\frac{1}{4}$ "	7	8	9	10	12	..	..	..	..	$\frac{3}{16}$ " $\frac{1}{4}$ "
$\frac{1}{4}$ " $\frac{5}{16}$ "	6	7	8	9	10	12	14	16	19	$\frac{1}{4}$ " $\frac{5}{16}$ "
$\frac{5}{16}$ " $\frac{3}{8}$ "	5	6	7	8	9	10	12	14	17	$\frac{5}{16}$ " $\frac{3}{8}$ "
$\frac{3}{8}$ " $\frac{7}{16}$ "	4.5	5	6	7	8	9	10	12	15	$\frac{3}{8}$ " $\frac{7}{16}$ "
$\frac{7}{16}$ " $\frac{1}{2}$ "	4	4.5	5	6	7	8	9	10	13	$\frac{7}{16}$ " $\frac{1}{2}$ "
$\frac{1}{2}$ " $\frac{5}{8}$ "	3.5	4	4.5	5	6	7	8	9	11	$\frac{1}{2}$ " $\frac{5}{8}$ "
$\frac{5}{8}$ " $\frac{3}{4}$ "	3	3.5	4	4.5	5	6	7	8	9	$\frac{5}{8}$ " $\frac{3}{4}$ "
$\frac{3}{4}$ " 1 "	2.5	3	3.5	4	4.5	5	6	7	8	$\frac{3}{4}$ " 1 "
1 or over	2.5	2.5	3	3.5	4	4.5	5	6	7	1 or over

specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection.

15. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 5 shall be reported within five working days from the receipt of samples.

(*b*) Material which shows injurious defects subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

Rehearing.

16. Samples tested in accordance with Section 5, which represent rejected material, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

STANDARD SPECIFICATIONS
FOR
BILLET-STEEL CONCRETE REINFORCEMENT BARS[1]

Serial Designation: A 15 – 14

These specifications are issued under the fixed designation A 15; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ADOPTED, 1911; REVISED, 1912, 1913, 1914.

Scope.

1. (*a*) These specifications cover three classes of billet-steel concrete reinforcement bars, namely: plain, deformed, and cold-twisted.

(*b*) Plain and deformed bars are of three grades, namely: structural-steel, intermediate and hard.

Basis of Purchase.

2. (*a*) The structural-steel grade shall be used unless otherwise specified.

(*b*) If desired, cold-twisted bars may be purchased on the basis of tests of the hot-rolled bars before twisting, in which case such tests shall govern and shall conform to the requirements specified for plain bars of structural-steel grade.

MANUFACTURE

Process.

3. (*a*) The steel shall be made by either or both the following processes: bessemer or open-hearth.

(*b*) The bars shall be rolled from new billets. No rerolled material will be accepted.

Cold-twisted Bars.

4. Cold-twisted bars shall be twisted cold with one complete twist in a length not over 12 times the thickness of the bar.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

5. The steel shall conform to the following requirements as to chemical composition:

Phosphorus	Bessemer	not over 0.10 per cent
	Open-hearth	" " 0.05 "

Ladle Analyses.

6. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus and sulfur. This analysis shall be made

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 5.

Check Analyses.

7. Analyses may be made by the purchaser from finished bars representing each melt of open-hearth steel, and each melt, or lot of ten tons, of Bessemer steel. The phosphorus content thus determined shall not exceed that specified in Section 5 by more than 25 per cent.

PHYSICAL PROPERTIES AND TESTS

Tension Tests.

8. (*a*) The bars shall conform to the following requirements as to tensile properties:

TENSILE PROPERTIES.

Properties Considered.	Plain Bars.			Deformed Bars.			Cold-twisted Bars.
	Structural-Steel Grade.	Intermediate Grade.	Hard Grade.	Structural-Steel Grade.	Intermediate Grade.	Hard Grade.	
Tensile strength, lb. per sq. in.....	55 000 to 70 000	70 000 to 85 000	80 000 min.	55 000 to 70 000	70 000 to 85 000	80 000 min.	Recorded only.
Yield point, min., lb. per sq. in.....	33 000	40 000	50 000	33 000	40 000	50 000	55 000
Elongation in 8 in., min., per cent.....	1 400 000[a] / Tens. str.	1 300 000[a] / Tens. str.	1 200 000[a] / Tens. str.	1 250 000[a] / Tens. str.	1 125 000[a] / Tens. str.	1 000 000[a] / Tens. str.	5

[a] See Section 9.

(*b*) The yield point shall be determined by the drop of the beam of the testing machine.

Modification in Elongation.

9. (*a*) For plain and deformed bars over $\frac{3}{4}$ in. in thickness or diameter, a deduction from the percentages of elongation specified in Section 8 (*a*) of 0.25 per cent shall be made for each increase of $\frac{1}{32}$ in. of the specified thickness or diameter above $\frac{3}{4}$ in.

(*b*) For plain and deformed bars under $\frac{7}{16}$ in. in thickness or diameter, a deduction from the percentages of elongation specified in Section 8 (*a*) of 0.5 per cent shall be made for each decrease of $\frac{1}{32}$ in. of the specified thickness or diameter below $\frac{7}{16}$ in.

Bend Tests.

10. The test specimen shall bend cold around a pin without cracking on the outside of the bent portion, as follows:

BEND-TEST REQUIREMENTS.

Thickness or Diameter of Bar.	Plain Bars.			Deformed Bars.			Cold-twisted Bars.
	Structural-Steel Grade.	Intermediate Grade.	Hard Grade.	Structural-Steel Grade.	Intermediate Grade.	Hard Grade.	
Under $\frac{3}{4}$ in.....	180 deg. d=t	180 deg. d=2t	180 deg. d=3t	180 deg. d=t	180 deg. d=3t	180 deg. d=4t	180 deg. d=2t
$\frac{3}{4}$ in. or over.....	180 deg. d=t	90 deg. d=2t	90 deg. d=3t	180 deg. d=2t	90 deg. d=3t	90 deg. d=4t	180 deg. d=3t

EXPLANATORY NOTE: d=the diameter of pin about which the specimen is bent;
t=the thickness or diameter of the specimen.

Test Specimens.

11. (*a*) Tension and bend test specimens for plain and deformed bars shall be taken from the finished bars, and shall be of the full thickness or diameter of bars as rolled; except that the specimens for deformed bars may be machined for a length of at least 9 in., if deemed necessary by the manufacturer to obtain uniform cross-section.

(*b*) Tension and bend test specimens for cold-twisted bars shall be taken from the finished bars, without further treatment; except as specified in Section 2 (*b*).

Number of Tests.

12. (*a*) One tension and one bend test shall be made from each melt of open-hearth steel, and from each melt, or lot of ten tons, of Bessemer steel; except that if material from one melt differs $\frac{3}{8}$ in. or more in thickness or diameter, one tension and one bend test shall be made from both the thickest and the thinnest material rolled.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 8 (*a*) and any part of the fracture is outside the middle third of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

PERMISSIBLE VARIATIONS IN WEIGHT

Permissible Variations.

13. The weight of any lot of bars shall not vary more than 5 per cent from the theoretical weight of that lot.

FINISH

Finish.

14. The finished bars shall be free from injurious defects and shall have a workmanlike finish.

INSPECTION AND REJECTION

15. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the bars ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the bars are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works **Inspection.**

16. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 7 shall be reported within five working days from the receipt of samples. **Rejection.**

(*b*) Bars which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

17. Samples tested in accordance with Section 7, which represent rejected bars, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time. **Rehearing.**

STANDARD SPECIFICATIONS
FOR
RAIL-STEEL CONCRETE REINFORCEMENT BARS[1]

Serial Designation: A 16 – 14

These specifications are issued under the fixed designation A 16; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

ADOPTED, 1913; REVISED, 1914.

Scope.

1. These specifications cover three classes of rail-steel concrete reinforcement bars: namely, plain, deformed, and hot-twisted.

MANUFACTURE

Process.

2. The bars shall be rolled from standard section Tee rails.

Hot-twisted Bars.

3. Hot-twisted bars shall have one complete twist in a length not over 12 times the thickness of the bar.

PHYSICAL PROPERTIES AND TESTS

Tension Tests.

4. (*a*) The bars shall conform to the following minimum requirements as to tensile properties:

Properties Considered.	Plain Bars.	Deformed and Hot-twisted bars.
Tensile strength, lb. per sq. in.	80 000	80 000
Yield point, lb. per sq. in.	50 000	50 000
Elongation in 8 in., per cent[1]	$\frac{1\,200\,000}{\text{Tens. str.}}$	$\frac{1\,000\,000}{\text{Tens. str.}}$

[1] See Section 5.

(*b*) The yield point shall be determined by the drop of the beam of the testing machine.

Modification in Elongation.

5. (*a*) For bars over $\frac{3}{4}$ in. in thickness or diameter, a deduction from the percentages of elongation specified in Section 4 (*a*) of 0.25 per cent shall be made for each increase of $\frac{1}{32}$ in. of the specified thickness or diameter above $\frac{3}{4}$ in.

(*b*) For bars under $\frac{7}{16}$ in. in thickness or diameter, a deduction from the percentages of elongation specified in Section

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

4 (*a*) of 0.5 per cent shall be made for each decrease of $\frac{1}{32}$ in. of the specified thickness or diameter below $\frac{7}{16}$ in.

Bend Tests.

6. The test specimen shall bend cold around a pin without cracking on the outside of the bent portion, as follows:

Thickness or Diameter of Bar.	Plain Bars.	Deformed and Hot-twisted Bars.
Under $\frac{3}{4}$ in.	180 deg. d = 3 t	180 deg. d = 4 t
$\frac{3}{4}$ in. or over	90 deg. d = 3 t	90 deg. d = 4 t

EXPLANATORY NOTE: d = the diameter of pin about which the specimen is bent;
t = the thickness or diameter of the specimen.

Test Specimens.

7. (*a*) Tension and bend test specimens for plain and deformed bars shall be taken from the finished bars, and shall be of the full thickness or diameter of bars as rolled; except that the specimens for deformed bars may be machined for a length of at least 9 in., if deemed necessary by the manufacturer to obtain uniform cross-section.

(*b*) Tension and bend test specimens for hot-twisted bars shall be taken from the finished bars, without further treatment.

Number of Tests.

8. (*a*) One tension and one bend test shall be made from each lot of ten tons or less of each size of bar rolled from rails varying not more than 10 lb. per yd. in nominal weight.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 4 (*a*) and any part of the fracture is outside the middle third of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

PERMISSIBLE VARIATIONS IN WEIGHT

Permissible Variation.

9. The weight of any lot of bars shall not vary more than 5 per cent from the theoretical weight of that lot.

FINISH

Finish.

10. The finished bars shall be free from injurious defects and shall have a workmanlike finish.

INSPECTION AND REJECTION

Inspection.

11. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser

is being performed, to all parts of the manufacturer's works which concern the manufacture of the bars ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the bars are being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection. 12. Bars which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

STANDARD SPECIFICATIONS

FOR

COLD-DRAWN STEEL WIRE FOR CONCRETE REINFORCEMENT[1]

Serial Designation: A 82–27

These specifications are issued under the fixed designation A 82; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1921; ADOPTED IN AMENDED FORM, 1927.

Scope.

1. These specifications cover cold-drawn steel wire to be used as such, or in fabricated form, for the reinforcement of concrete, in gages not less than 0.080 in. nor greater than 0.625 in.

Basis of Purchase.

2. When wire is ordered by gage number the following relation between number and diameter, in inches, shall apply unless otherwise specified:

Gage Number	Equivalent Diameter, in.	Gage Number	Equivalent Diameter, in.
0000000	0.4900	5	0.2070
000000	0.4615	6	0.1920
00000	0.4305	7	0.1770
0000	0.3938	8	0.1620
000	0.3625	9	0.1483
00	0.3310	10	0.1350
0	0.3065	11	0.1205
1	0.2830	12	0.1055
2	0.2625	13	0.0915
3	0.2437	14	0.0800
4	0.2253		

MANUFACTURE

Process.

3. (*a*) The steel shall be made by either or both the following processes: bessemer or open-hearth.

Drawing.

(*b*) The wire shall be cold drawn from rods hot-rolled from billets.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

PHYSICAL PROPERTIES AND TESTS

Tension Tests.

4. (*a*) The wire, except as specified in Paragraphs (*b*) and (*c*), shall conform to the following minimum requirements as to tensile properties:

Tensile strength, lb. per sq. in.	80,000
Reduction of area, per cent	30

(*b*) For wire to be used in the fabrication of mesh a minimum tensile strength of 70,000 lb. per sq. in. shall be permitted.

(*c*) For wire testing over 100,000 lb. per sq. in. tensile strength, the reduction of area shall be not less than 25 per cent.

Bend Tests.

5. The test specimen shall stand being bent cold through 180 deg. without cracking on the outside of the bent portion, as follows:

For wire 0.3 in. in diameter or under, around a pin the diameter of which is equal to the diameter of the specimen.

For wire over 0.3 in. in diameter, around a pin the diameter of which is equal to twice the diameter of the specimen.

Test Specimens.

6. Tension and bend test specimens shall be of the full-size section of the wire as drawn.

Number of Tests.

7. (*a*) One tension and one bend test shall be made for each 10 tons or less of each size of wire.

(*b*) If any test specimen shows defects or develops flaws, it may be discarded and another specimen substituted.

PERMISSIBLE VARIATIONS IN GAGE

Permissible Variations.

8. The diameter of the wire shall not vary more than 0.003 in. from the size ordered.

FINISH

Finish.

9. The finished wire shall be free from injurious defects and shall have a workmanlike finish with smooth surface.

INSPECTION AND REJECTION

Inspection.

10. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the wire is being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection.

11. Wire which shows injurious defects subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

STANDARD SPECIFICATIONS
FOR
COMMERCIAL QUALITY HOT-ROLLED BAR STEELS[1]

Serial Designation: A 107 – 27

These specifications are issued under the fixed designation A 107; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1926; ADOPTED IN AMENDED FORM, 1927.

Scope.

1. These specifications cover hot-rolled carbon-steel bars produced in accordance with good mill practice for general commercial purposes. The sections covered are rounds, squares, and hexagons of all sizes, and flats not over 6 in. wide.

Basis of Purchase.

2. The purchaser shall specify each grade desired by its grade designation or by its complete chemical limits.

MANUFACTURE

Process.

3. The steel shall be made by the open-hearth or bessemer process, as specified.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

4. The steel shall conform to the requirements as to chemical composition specified in Table I for the respective grades.

Ladle Analyses.

5. (*a*) For bessemer steel a carbon determination shall be made of each melt; and determinations for manganese, phosphorus and sulfur, representing the average of the melts made in each twelve-hour period.

(*b*) For open-hearth steel an analysis of each melt shall be made for carbon, manganese, phosphorus and sulfur.

(*c*) These analyses shall be made by the manufacturer from test ingots taken during the pouring of each melt. The chemical composition thus determined shall conform to the requirements specified, and shall be reported to the purchaser or his representative if requested.

Check Analyses.

6. (*a*) Analyses may be made by the purchaser from finished bars representing each melt of open-hearth steel, and each melt, or

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

TABLE I.—GRADES AND CHEMICAL COMPOSITIONS.

Grades	Carbon, per cent	Manganese, per cent	Phosphorus, per cent	Sulfur, per cent
OPEN-HEARTH GRADES				
Open-Hearth Dead Soft	0.12 max.	0.55 max.	0.04 max.	0.055 max.
Open-Hearth 05 – 15 Carbon	0.05 – 0.15	0.30 – 0.60	0.045 max.	0.055 max.
Open-Hearth 10 – 20 Carbon	0.10 – 0.20	0.30 – 0.60	0.045 max.	0.055 max.
Open-Hearth 15 – 25 Carbon	0.15 – 0.25	0.30 – 0.60	0.045 max.	0.055 max.
Open-Hearth 20 – 30 Carbon	0.20 – 0.30	0.50 – 0.80	0.045 max.	0.055 max.
Open-Hearth 25 – 35 Carbon	0.25 – 0.35	0.50 – 0.80	0.045 max.	0.055 max.
Open-Hearth 30 – 40 Carbon	0.30 – 0.40	0.50 – 0.80	0.045 max.	0.055 max.
Open-Hearth 35 – 45 Carbon	0.35 – 0.45	0.50 – 0.80	0.045 max.	0.055 max.
Open-Hearth 40 – 50 Carbon	0.40 – 0.50	0.50 – 0.80	0.045 max.	0.055 max.
Open-Hearth 45 – 55 Carbon	0.45 – 0.55	0.50 – 0.80	0.045 max.	0.055 max.
Open-Hearth 50 – 65 Carbon	0.50 – 0.65	0.50 – 0.80	0.045 max.	0.055 max.
Open-Hearth 55 – 70 Carbon	0.55 – 0.70	0.50 – 0.80	0.045 max.	0.055 max.
Open-Hearth 60 – 75 Carbon	0.60 – 0.75	0.50 – 0.80	0.045 max.	0.055 max.
Open-Hearth 65 – 80 Carbon	0.65 – 0.80			
BESSEMER GRADES				
Bessemer Welding	0.12 max.	0.60 max.	0.11 max.	0.08 max.
Bessemer Soft	0.15 max.	0.70 max.	0.11 max.	.....
Bessemer 15 – 25 Carbon	0.15 – 0.25	0.90 max.	0.11 max.	.....
Bessemer 25 – 35 Carbon	0.25 – 0.35	0.90 max.	0.11 max.	.....
Bessemer 35 – 50 Carbon	0.35 – 0.50	0.90 max.	0.11 max.	.....
SCREW STEEL GRADES				
Bessemer Screw	0.08 – 0.16	0.60 – 0.90	0.09 – 0.13	0.075 – 0.15
Open-Hearth Screw	0.15 – 0.25	0.60 – 0.90	0.06 max.	0.075 – 0.15

TABLE II.—PERMISSIBLE VARIATIONS IN THE SIZES OF BARS.

HOT-ROLLED BARS

Rounds, Squares and Hexagons: Sizes Specified	Variations in Size, in.	
	Under	Over
Up to $\frac{1}{2}$ in., inclusive	0.007	0.007
Over $\frac{1}{2}$ to 1 " "	0.010	0.010
" 1 to 2 " "	$\frac{1}{64}$	$\frac{1}{32}$
" 2 to 3 " "	$\frac{1}{32}$	$\frac{3}{64}$
" 3 to 5 " "	$\frac{1}{32}$	$\frac{3}{32}$
" 5 to 8 " "	$\frac{1}{16}$	$\frac{1}{8}$

Flats: Widths Specified	Variations in Width, in.		Variations in Thickness, Under and Over, in., for Thicknesses Specified			
	Under	Over	$\frac{3}{16}$ in. or Under	Over $\frac{3}{16}$ to $\frac{1}{2}$ in., incl.	Over $\frac{1}{2}$ to 1 in., incl.	Over 1 to 2 in., incl.
Up to 1 in., inclusive	$\frac{1}{64}$	$\frac{1}{32}$	0.006	0.008	0.010	....
Over 1 to 2 " "	$\frac{1}{32}$	$\frac{3}{64}$	0.008	0.012	0.015	$\frac{1}{32}$
" 2 to 4 " "	$\frac{3}{64}$	$\frac{1}{16}$	0.010	0.015	0.020	$\frac{1}{32}$
" 4 to 6 " "	$\frac{1}{16}$	$\frac{3}{32}$	0.010	0.015	0.020	$\frac{1}{32}$

lot of bars, of bessemer steel. The average chemical composition thus determined shall not vary from the limits specified more than 0.03 per cent over or 0.02 per cent under in carbon; 0.03 per cent over or 0.02 per cent under in manganese; 0.005 per cent over in phosphorus; and 0.005 per cent over in sulfur.

(*b*) Samples for analysis shall be taken by machining off the entire cross-section of the bar, or by drilling parallel to the axis of the bar at any point midway between the center and surface.

(*c*) The minimum number of samples to be taken from material representing the same melt or lot, before rejection by the purchaser shall be:

3 for 5 tons or less;
4 for over 5 tons to 10 tons;
5 for over 10 tons to 15 tons;
6 for over 15 tons.

(*d*) In case the number of pieces in a melt is less than the number of samples given, one sample from each piece shall be considered sufficient.

(*e*) Separate determinations shall be made on each sample and the results averaged, unless they clearly indicate mixed grades.

PERMISSIBLE VARIATIONS IN DIMENSIONS

Permissible Variations.

7. The variation from the specified diameter, or distance between parallel faces, shall not exceed the limits specified in Table II.

FINISH

Finish.

8. The material shall be free from injurious defects and shall have a workmanlike finish.

INSPECTION AND REJECTION

Inspection.

9. The inspector representing the purchaser shall have free entry at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection.

10. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 6 shall be reported within five working days from the receipt of samples.

(*b*) Material which shows injurious defects subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

Rehearing.

11. Samples tested in accordance with Section 6 which represent rejected material shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

STANDARD SPECIFICATIONS

FOR

COMMERCIAL COLD-FINISHED BAR STEELS AND COLD-FINISHED SHAFTING[1]

Serial Designation: A 108 – 27

These specifications are issued under the fixed designation A 108; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1926; ADOPTED IN AMENDED FORM, 1927.

Scope.

1. (*a*) These specifications cover commercial cold-finished bar steels of grades considered to be in common use, including cold-finished bessemer screw stock and cold-finished open-hearth screw stock, also cold-finished shafting and commercial key stock.

(*b*) The sections of bar steel covered are rounds, squares and hexagons of all sizes, and flats not over 6 in. wide. The sections of shafting covered are rounds up to 6 in., inclusive.

Basis of Purchase.

2. (*a*) Bars and shafting may be cold-rolled, cold-drawn, turned and polished, or turned and ground.

(*b*) The purchaser shall specify each grade of bar steel desired, by its grade designation or by its complete chemical limits.

(*c*) The steel in bessemer and open-hearth screw stock shall be free-cutting and suitable for high-speed screw machine work, leaving a smooth finish after machining under proper conditions.

(*d*) Cold-finished shafting, when not specified by the purchaser in any particular grade, shall be in such grades as are in accordance with the manufacturer's practice for the respective sizes.

MANUFACTURE

Process.

3. (*a*) Bar steel shall be made by the open-hearth or bessemer process, as specified.

(*b*) Shafting shall be made by either or both the following processes: bessemer or open-hearth.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

4. Bar steel shall conform to the requirements as to chemical composition specified in Tables I and II for the respective grades.

Analysis Reports.

5. An analysis of each melt of open-hearth steel shall be furnished by the manufacturer when requested, showing the percentages of the elements specified, which shall conform to the requirements for the grade specified in Table I.

Check Analyses.

6. (*a*) Analyses may be made by the purchaser from finished bars representing each melt of open-hearth steel, and each melt, or lot of ten tons, of bessemer steel. The chemical composition thus

TABLE I.—GRADES AND CHEMICAL COMPOSITIONS FOR COMMERCIAL COLD-FINISHED BAR STEELS.

Grades	Carbon, per cent	Manganese, per cent	Phosphorus, per cent	Sulfur, per cent
OPEN-HEARTH GRADES				
Open-Hearth 05 - 15 Carbon	0.05 - 0.15	0.30 - 0.60	0.045 max.	0.05 max.
Open-Hearth 10 - 20 Carbon	0.10 - 0.20	0.30 - 0.60	0.045 max.	0.05 max.
Open-Hearth 15 - 25 Carbon	0.15 - 0.25	0.30 - 0.60	0.045 max.	0.05 max.
Open-Hearth 20 - 30 Carbon	0.20 - 0.30	0.50 - 0.80	0.045 max.	0.05 max.
Open-Hearth 25 - 35 Carbon	0.25 - 0.35	0.50 - 0.80	0.045 max.	0.05 max.
Open-Hearth 30 - 40 Carbon	0.30 - 0.40	0.50 - 0.80	0.045 max.	0.05 max.
Open-Hearth 35 - 45 Carbon	0.35 - 0.45	0.50 - 0.80	0.045 max.	0.05 max.
Open-Hearth 40 - 50 Carbon	0.40 - 0.50	0.50 - 0.80	0.045 max.	0.05 max.
BESSEMER GRADES				
Bessemer Soft	0.15 max.	0.60 max.	0.11 max.	.....
SCREW-STEEL GRADES				
Bessemer Screw	0.08 - 0.16	0.60 - 0.90	0.09 - 0.13	0.075 - 0.15
Open-Hearth Screw	0.15 - 0.25	0.60 - 0.90	0.06 max.	0.075 - 0.15

determined shall conform to the requirements in Table I, with the permissible variations in ranges and in maximum limits specified in Table II.

(*b*) Samples for analysis shall be taken by machining off the entire cross-section of the bar, or by drilling parallel to the axis of the bar at any point midway between the center and surface.

PERMISSIBLE VARIATIONS IN DIMENSIONS

Permissible Variations.

7. The variation from the specified diameters, or distances between parallel faces, of cold-finished bars specified in carbon up to and including 0.30 per cent, shall not exceed the limits specified in Table III. For bars specified in carbon over 0.30 per cent, the variations shall be a matter of agreement between the purchaser and the manufacturer.

TABLE II.—VARIATIONS IN RANGES AND IN MAXIMUM LIMITS SPECIFIED IN TABLE I PERMITTED ON CHECK ANALYSIS. (Open-hearth and bessemer screw stock not included.)

Grades	Permissible Variations from Limits Specified in Table I					
	Carbon		Manganese		Phosphorus	Sulfur
	Under Lower Limit	Over Upper Limit	Under Lower Limit	Over Upper Limit	Over Maximum	Over Maximum
OPEN-HEARTH GRADES						
Open-Hearth 05 – 15 Carbon	.....	0.03	0.05	0.05	0.01	0.01
Open-Hearth 10 – 20 and 12 – 25 Carbon	0.02	0.04	0.05	0.05	0.01	0.01
Open-Hearth 20 – 30 and 25 – 35 Carbon	0.03	0.05	0.05	0.10	0.01	0.01
Open-Hearth 30 – 40 and 35 – 45 Carbon	0.03	0.06	0.05	0.10	0.01	0.01
Open-Hearth 40 – 50 Carbon	0.03	0.07	0.05	0.10	0.01	0.01
BESSEMER GRADES						
Bessemer Soft	.....	0.03	.....	0.05	0.02	.....

TABLE III.—PERMISSIBLE VARIATIONS IN THE SIZES OF COLD-FINISHED BARS.

Specified Dimensions	Variations in Diameter, Thickness or Width, in.							
	Rounds and Hexagons		Squares		Flats up to 1½ in., inclusive, in Width		Flats over 1½ in. in Width	
	Under	Over	Under	Over	Under	Over	Under	Over
Up to 0.3 in., inclusive	0.002	0	0.003	0	0.003	0	0.005	0
Over 0.3 to 1 " "	0.003	0	0.004	0	0.004	0	0.005	0
" 1 to 2½ " "	0.004	0	0.005	0	0.005	0	0.006	0
" 2½ " "	0.005	0	0.006	0	....	..	....	..
" 2½ to 4 " "	....	..	....	..	....	..	0.007	0
" 4 to 6 " "	....	..	....	..	....	..	0.010	0

TABLE IV.—PERMISSIBLE VARIATIONS IN THE SIZES OF COLD-FINISHED SHAFTING.

Diameters Specified	Variations in Dimensions, in.	
	Under	Over
ROUND SHAFTING		
Up to 1 in., inclusive	0.002	0
1 1/16 to 2 " "	0.003	0
2 1/16 to 4 " "	0.004	0
4 1/16 to 6 " "	0.005	0

(*b*) The variations from the specified diameters of cold-finished shafting shall not exceed the limits specified in Table IV.

FINISH

Finish. 8. The material shall be free from injurious defects and shall have a bright smooth surface.

INSPECTION AND REJECTION

Inspection. 9. The manufacturer shall afford the inspector representing the purchaser, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications.

Rejection. 10. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 6 shall be reported within five working days from the receipt of samples.

(*b*) Material which shows injurious defects subsequent to acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

Rehearing. 11. Samples tested in accordance with Section 6 which represent rejected material shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

STANDARD SPECIFICATIONS
FOR
CARBON-STEEL BARS FOR RAILWAY SPRINGS[1]

Serial Designation: A 14 – 27

These specifications are issued under the fixed designation A 14; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ADOPTED, 1914; REVISED, 1916, 1927.

Scope.

1. These specifications cover two grades of carbon-steel bars to be used for the manufacture of railway springs, determined by the carbon ranges specified in Section 3. The choice of the grade of bar to be used for the manufacture of any spring will depend on the design of the spring and the stresses and service for which it is intended. The purposes for which these grades are frequently used are as follows:

Grade A, for elliptical and helical springs;
Grade B, for helical springs.

MANUFACTURE

Process.

2. The steel shall be made by one or more of the following processes: open-hearth, crucible or electric furnace.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

3. The steel shall conform to the following requirements as to chemical composition:

ELEMENTS CONSIDERED.	GRADE A.	GRADE B.
Carbon, per cent	0.90 – 1.10	0.95 – 1.15
Manganese, max., per cent	0.50	0.50
Phosphorus, max., per cent	0.05	0.05
Sulfur, max., per cent	0.05	0.05

Ladle Analyses.

4. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements specified in Section 3. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 3.

Check Analyses. 5. An analysis may be made by the purchaser from a finished bar representing each melt. The chemical composition thus determined shall conform to the requirements specified in Section 3.

PERMISSIBLE VARIATIONS IN DIMENSIONS

Permissible Variations. 6. The permissible variations in the width and thickness of the bars shall be:

FLATS

	Variations in Width, in.		Variations in Thickness, in.			
			Up to $\frac{3}{8}$ in., Inclusive		Over $\frac{3}{8}$ to $\frac{5}{8}$ in., Inclusive	
	Over	Under	Over	Under	Over	Under
1 to 2 in., incl.	0.030	0.015	0.015	0.005	0.015	0.010
Over 2 to 4 in., incl.	0.047	0.015	0.015	0.005	0.015	0.010
Over 4 to 6 in., incl.	0.062	0.032	0.015	0.005	0.015	0.010

ROUNDS AND SQUARES

	Variations in Diameter or Thickness, in.	
	Over	Under
Up to $\frac{1}{2}$ in., incl.	0.007	0.007
Over $\frac{1}{2}$ to 1 in., incl.	0.010	0.010
Over 1 to 2 in., incl.	0.016	0.016

FINISH

Finish. 7. The finished bars shall be free from injurious defects and shall have a workmanlike finish.

MARKING

Marking. 8. The bars shall, when loaded for shipment, be properly separated and marked with the name or brand of the manufacturer and the melt number for identification.

INSPECTION AND REJECTION

Inspection. 9. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the bars ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the bars are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall

be so conducted as not to interfere unnecessarily with the operation of the works.

10. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 5 shall be reported within five working days from the receipt of samples. Rejection.

(*b*) Bars which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

11. Samples tested in accordance with Section 5, which represent rejected bars, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time. Rehearing.

STANDARD SPECIFICATIONS
FOR
CARBON-STEEL BARS FOR RAILWAY SPRINGS WITH SPECIAL SILICON REQUIREMENTS[1]

Serial Designation: A 68 – 27

These specifications are issued under the fixed designation A 68; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1916; ADOPTED, 1918; REVISED, 1927.

Scope.

1. These specifications cover two grades of carbon-steel bars with special silicon requirements to be used for the manufacture of railway springs, determined by the carbon ranges specified in Section 3. The choice of the grade of bar to be used for the manufacture of any spring will depend on the design of the spring and the stresses and service for which it is intended. The purposes for which these grades are frequently used are as follows:

Grade A, for elliptical and helical springs;

Grade B, for helical springs.

MANUFACTURE

Process.

2. The steel shall be made by one or more of the following processes: open-hearth, crucible or electric-furnace.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

3. The steel shall conform to the following requirements as to chemical composition:

Elements Considered	Grade A	Grade B
Carbon, per cent	0.90 – 1.10	0.95 – 1.15
Manganese, max., per cent	0.50	0.50
Phosphorus, max., per cent	0.05	0.05
Sulfur, max., per cent	0.05	0.05
Silicon, per cent	0.25 – 0.50	0.25 – 0.50

[1]Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

4. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements specified in Section 3. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 3. **Ladle Analyses.**

5. An analysis may be made by the purchaser from a finished bar representing each melt. The chemical composition thus determined shall conform to the requirements specified in Section 3. **Check Analyses.**

PERMISSIBLE VARIATIONS IN DIMENSIONS

6. The permissible variations in width and thickness of the bars shall be: **Permissible Variations.**

FLATS

	Variations in Width, in.		Variations in Thickness, in. Up to $\frac{3}{8}$ in., Inclusive		Variations in Thickness, in. Over $\frac{3}{8}$ to $\frac{5}{8}$ in., Inclusive	
	Over	Under	Over	Under	Over	Under
1 to 2 in., incl.....	0.030	0.015	0.015	0.005	0.015	0.010
Over 2 to 4 in., incl...	0.047	0.015	0.015	0.005	0.015	0.010
Over 4 to 6 in., incl...	0.062	0.032	0.015	0.005	0.015	0.010

ROUNDS AND SQUARES

	Variations in Diameter or Thickness, in.	
	Over	Under
Up to $\frac{1}{2}$ in., incl.....	0.007	0.007
Over $\frac{1}{2}$ to 1 in., incl.....	0.010	0.010
Over 1 to 2 in., incl.....	0.016	0.016

FINISH

7. The finished bars shall be free from injurious defects and shall have a workmanlike finish. **Finish.**

MARKING

8. The bars shall, when loaded for shipment, be properly separated and marked with the name or brand of the manufacturer and the melt number for identification. **Marking.**

INSPECTION AND REJECTION

9. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the bars ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the bars are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the **Inspection.**

place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection.

10. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 5 shall be reported within five working days from the receipt of samples.

(*b*) Bars which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

Rehearing.

11. Samples tested in accordance with Section 5, which represent rejected bars, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

STANDARD SPECIFICATIONS
FOR
CARBON-STEEL BARS FOR VEHICLE AND GENERAL PURPOSE SPRINGS[1]

Serial Designation: A 58 – 27

These specifications are issued under the fixed designation A 58; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ADOPTED, 1916; REVISED, 1927.

Scope.

1. These specifications cover two grades of carbon-steel bars to be used for the manufacture of vehicle and general purpose springs, determined by the carbon ranges specified in Section 3. The choice of the grade of bar to be used for the manufacture of any spring will depend on the design of the spring and the stresses and service for which it is intended.

MANUFACTURE

Process.

2. The steel shall be made by one or more of the following processes: open-hearth, crucible or electric-furnace.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

3. The steel shall conform to the following requirements as to chemical composition:

Elements Considered		Grade A	Grade B
Carbon, per cent		0.85 – 1.05	0.90 – 1.05
Manganese, per cent		0.25 – 0.50	0.25 – 0.50
Phosphorus, max., per cent	Acid	0.05	0.05
	Basic	0.05	0.04
Sulfur, max., per cent		0.05	0.05

Ladle Analyses.

4. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements specified in Section 3. This analysis shall be made from a test ingot taken dur-

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

ing the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 3.

Check Analyses.

5. An analysis may be made by the purchaser from a finished bar representing each melt. The chemical composition thus determined shall conform to the requirements specified in Section 3.

PERMISSIBLE VARIATIONS IN DIMENSIONS

Permissible Variations.

6. The permissible variations in the width and thickness of the bars shall be agreed upon by the manufacturer and the purchaser.

FINISH

Finish.

7. The finished bars shall be free from injurious defects and shall have a workmanlike finish.

MARKING

Marking.

8. The bars shall, when loaded for shipment, be properly separated and marked with the name or brand of the manufacturer and the melt number for identification.

INSPECTION AND REJECTION

Inspection.

9. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the bars ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the bars are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection.

10. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 5 shall be reported within five working days from the receipt of samples.

(*b*) Bars which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

Rehearing.

11. Samples tested in accordance with Section 5, which represent rejected bars, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

STANDARD SPECIFICATIONS
FOR
SILICO-MANGANESE-STEEL BARS FOR RAILWAY SPRINGS[1]

Serial Designation: A 59–27

These specifications are issued under the fixed designation A 59; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ADOPTED, 1916; REVISED, 1927.

Scope.

1. These specifications cover silico-manganese-steel bars to be used for the manufacture of railway springs.

MANUFACTURE

Process.

2. The steel shall be made by one or more of the following processes: open-hearth, crucible or electric-furnace.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition

3. The steel shall conform to the following requirements as to chemical composition:

Carbon, per cent	0.55 – 0.65
Manganese, per cent	0.60 – 0.90
Silicon, per cent	1.80 – 2.20
Phosphorus, per cent	not over 0.045
Sulfur, per cent	not over 0.045

Ladle Analyses.

4. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements specified in Section 3. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 3.

Check Analyses.

5. An analysis may be made by the purchaser from a finished bar representing each melt. The chemical composition thus determined shall conform to the requirements specified in Section 3.

PERMISSIBLE VARIATIONS IN DIMENSIONS

Permissible Variations.

6. The permissible variations in width and thickness of the bars shall be:

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

FLATS

	Variations in Width, in.		Variations in Thickness, in.			
			Up to $\frac{3}{8}$ in., Inclusive		Over $\frac{3}{8}$ to $\frac{5}{8}$ in., Inclusive	
	Over	Under	Over	Under	Over	Under
1 to 2 in., incl.....	0.030	0.015	0.015	0.005	0.015	0.010
Over 2 to 4 in., incl...	0.047	0.015	0.015	0.005	0.015	0.010
Over 4 to 6 in., incl...	0.062	0.032	0.015	0.005	0.015	0.010

ROUNDS AND SQUARES

	Variations in Diameter or Thickness, in.	
	Over	Under
Up to $\frac{1}{2}$ in., incl.....	0.007	0.007
Over $\frac{1}{2}$ to 1 in., incl.....	0.010	0.010
Over 1 to 2 in., incl.....	0.016	0.016

FINISH

Finish. 7. The finished bars shall be free from injurious defects and shall have a workmanlike finish.

MARKING

Marking. 8. The bars shall, when loaded for shipment, be properly separated and marked with the name or brand of the manufacturer and the melt number for identification.

INSPECTION AND REJECTION

Inspection. 9. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the bars ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the bars are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection. 10. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 5 shall be reported within five working days from the receipt of samples.

(*b*) Bars which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

Rehearing. 11. Samples tested in accordance with Section 5, which represent rejected bars, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

STANDARD SPECIFICATIONS
FOR
CHROME-VANADIUM-STEEL BARS FOR RAILWAY SPRINGS[1]

Serial Designation: A 60 – 27

These specifications are issued under the fixed designation A 60; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ADOPTED, 1916; REVISED, 1927.

Scope.

1. These specifications cover chrome-vanadium-steel bars to be used for the manufacture of railway springs.

MANUFACTURE

Process.

2. The steel shall be made by one or more of the following processes: open-hearth, crucible or electric-furnace.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

3. The steel shall conform to the following requirements as to chemical composition:

Carbon, per cent		0.50 – 0.60
Manganese, per cent		0.60 – 0.90
Chromium, per cent		0.90 – 1.10
Phosphorus, per cent	not over	0.045
Sulfur, per cent	not over	0.045
Vanadium, per cent	not under	0.15

Ladle Analyses.

4. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements specified in Section 3. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 3.

Check Analyses.

5. An analysis may be made by the purchaser from a finished bar representing each melt. The chemical composition thus determined shall conform to the requirements specified in Section 3.

PERMISSIBLE VARIATIONS IN DIMENSIONS

Permissible Variations.

6. The permissible variations in width and thickness of the bars shall be:

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

FLATS

	Variations in Width, in.		Variations in Thickness, in. Up to $\frac{3}{8}$ in., Inclusive		Variations in Thickness, in. Over $\frac{3}{8}$ to $\frac{5}{8}$ in., Inclusive	
	Over	Under	Over	Under	Over	Under
1 to 2 in., incl.....	0.030	0.015	0.015	0.005	0.015	0.010
Over 2 to 4 in., incl...	0.047	0.015	0.015	0.005	0.015	0.010
Over 4 to 6 in., incl...	0.062	0.032	0.015	0.005	0.015	0.010

ROUNDS AND SQUARES

	Variations in Diameter or Thickness, in.	
	Over	Under
Up to $\frac{1}{2}$ in., incl.....	0.007	0.007
Over $\frac{1}{2}$ to 1 in., incl.....	0.010	0.010
Over 1 to 2 in., incl.....	0.016	0.016

FINISH

Finish. 7. The finished bars shall be free from injurious defects and shall have a workmanlike finish.

MARKING

Marking. 8. The bars shall, when loaded for shipment, be properly separated and marked with the name or brand of the manufacturer and the melt number for identification.

INSPECTION AND REJECTION

Inspection. 9. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the bars ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the bars are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection. 10. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 5 shall be reported within five working days from the receipt of samples.

(*b*) Bars which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

Rehearing. 11. Samples tested in accordance with Section 5, which represent rejected bars, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

STANDARD SPECIFICATIONS
FOR
HELICAL STEEL SPRINGS FOR RAILWAYS[1]

Serial Designation: A 61 - 16

These specifications are issued under the fixed designation A 61; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

ADOPTED, 1916.

Scope.

1. These specifications cover all helical steel springs for suspension, draft and buffer purposes for locomotives, tenders and cars.

Basis of Purchase.

2. (*a*) The springs shall be made of carbon-steel bars conforming to the requirements of the Standard Specifications for Carbon-Steel Bars for Railway Springs (Serial Designation: A 14) of the American Society for Testing Materials,[2] unless otherwise specified.

(*b*) If carbon-steel bars with special silicon requirements or alloy-steel bars are specified, the manufacturer and the purchaser shall agree upon the type and grade of the bars to be used; in which case the bars shall conform, for the respective types, to the Standard Specifications for Carbon-Steel Bars for Railway Springs with Special Silicon Requirements (Serial Designation: A 68),[3] the Standard Specifications for Silico-Manganese-Steel Bars for Railway Springs (Serial Designation: A 59),[4] or the Standard Specifications for Chrome-Vanadium-Steel Bars for Railway Springs (Serial Designation: A 60),[5] of the American Society for Testing Materials.

(*c*) Drillings for chemical analysis shall be taken from pieces sheared from the bars during the process of manufacture, and not from a finished spring, unless otherwise agreed upon.

CHEMICAL PROPERTIES AND TESTS

Check Analyses.

3. (*a*) An analysis may be made by the purchaser from a sample representing each size of spring steel involved. The

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

[2] See p. 149. [3] See p. 152. [4] See p. 157. [5] See p. 159.

chemical composition thus determined shall conform to the requirements specified in Section 2 (*a*) or (*b*).

(*b*) Drillings for analysis shall be taken from the unworked portion of the bars and shall represent the full cross-section after rejecting any decarburized material.

(*c*) In case of dispute, check and arbitration analyses of carbon steel shall be made in accordance with the Standard Methods of Chemical Analysis of Plain Carbon Steel (Serial Designation: A 33) of the American Society for Testing Materials,[1] the carbon being determined by the "direct-combustion" method; and of alloy steel, in accordance with the Standard Methods of Chemical Analysis of Alloy Steels (Serial Designation: A 55) of the American Society for Testing Materials.[2]

WORKMANSHIP

Inspection. 4. The purchaser or his representative may examine all springs in each lot for workmanship and general dimensions.

Workmanship. 5. (*a*) The springs shall be submitted for inspection complete in the condition required by the drawings, and shall conform to these drawings with the permissible variations specified in this Section and Section 7.

(*b*) The springs shall be of uniform pitch with ends tapered to give a reasonably square, firm bearing. The points of bars shall not protrude beyond the outside diameter of the springs.

(*c*) The outside dimensions of the springs, excepting the height, shall not vary more than $\frac{1}{16}$ in. from those specified.

PHYSICAL PROPERTIES AND TESTS

Number of Tests. 6. (*a*) From each lot of springs which has met the requirements of Section 5, the purchaser or his representative may select for physical tests at least 10 per cent, to be tested in accordance with the requirements of Section 7 and the appendix.

(*b*) If any of the springs representing a lot fail to meet the requirements as to physical properties specified in Section 7, but at least half of the springs representing a lot do meet these requirements, each spring of the lot shall be tested and those which meet the requirements shall be accepted. If more than half of the springs representing a lot fail to meet the requirements specified in Section 7, the lot represented will be rejected.

Physical Tests. 7. The properties specified in Paragraphs (*a*), (*b*), (*c*) and (*d*), modified if necessary to conform to the requirements of the appendix, shall be determined in the order specified. The

[1] See p. 276. [2] See p. 300.

spring shall not be rapped or otherwise disturbed during the test.

(*a*) *Solid Height.*—The solid height is the perpendicular distance between the plates of the testing machine when the spring is compressed solid with a test load at least $1\frac{1}{4}$ times that necessary to bring all the coils in contact. The solid height shall not vary more than $\frac{1}{8}$ in. from that specified.

(*b*) *Free Height.*—The free height is the height of the spring when the load specified in Paragraph (*a*) has been released, and is determined by placing a straight edge across the top of the spring and measuring the perpendicular distance from the plate on which the spring stands to the straight edge, at the approximate center of the spring. The free height shall not vary more than $\frac{1}{8}$ in. from that specified.

(*c*) *Loaded Height.*—The loaded height is the distance between the plates of the testing machine when the specified working load is applied. The loaded height shall not vary more than $\frac{1}{8}$ in. over nor more than $\frac{1}{16}$ in. under that specified.

(*d*) *Permanent Set.*—The permanent set is the difference, if any, between the free height and the height (measured at the same point and in a similar manner) after the spring has been compressed solid three times in rapid succession with the test load specified in Paragraph (*a*). The permanent set shall not exceed $\frac{1}{32}$ in.

MARKING

Marking.

8. (*a*) The name or brand of the manufacturer, the year and month of manufacture, and if specified, the purchaser's class number, shall be legibly stamped on each spring at a place not detrimental to the life or service of the spring.

(*b*) Any stamping by the inspector shall be so placed as not to be detrimental to the life or service of the spring.

INSPECTION AND REJECTION

Inspection.

9. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the springs ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the springs are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be

so conducted as not to interfere unnecessarily with the operation of the works.

Rejection. 10. Unless otherwise specified, any rejection based on tests made in accordance with Section 3 shall be reported within five working days from the receipt of samples.

Rehearing. 11. Samples tested in accordance with Section 3, which represent rejected springs, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

Reworking. 12. Any springs which fail to meet the requirements as to dimensions or physical tests may be again submitted after being worked.

APPENDIX.

TEST FIBER STRESS.

13. (*a*) The properties and methods of testing specified in Section 7 have been established for carbon-steel springs on the assumption that the maximum fiber stress under test shall not exceed 90,000 lb. per sq. in.[1]

(*b*) For alloy-steel springs practice has not been sufficiently well established to enable definite fiber stresses to be given. Unless otherwise agreed upon by the manufacturer and the purchaser, alloy-steel springs shall be tested under the conditions as to fiber stress specified for carbon-steel springs.

RELATION BETWEEN FIBER STRESS AND LOAD.

14. To find the maximum load under which the conditions of Section 13 (*a*) are fulfilled, the following formula shall be used:

$$P = \frac{3.1416\, S\, d^3}{8\, M} \qquad (1)$$

where P = the load in pounds; S = the stress of the most strained fiber in pounds per square inch; d = the diameter of the bar in

[1] This stress is given solely as a limiting stress not to be exceeded in testing by the methods covered by the specifications. It is not intended as a guide in the design of springs, as the proper working fiber stress will depend on the class and design of the spring and on the service for which it is intended.

TABLE I.—TEST LOADS FOR HELICAL SPRINGS, IN POUNDS, WHICH WILL CORRESPOND TO A MAXIMUM FIBER STRESS OF 90,000 LB. PER SQ. IN.

Outside Diameter of Spring, in.	Diameter of Bar, in.																				Outside Diameter of Spring, in.
	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4	13/16	7/8	15/16	1	1 1/16	1 1/8	1 3/16	1 1/4	1 5/16	1 3/8	1 7/16	1 1/2	1 9/16	
2	640	1 145	1 895	2 950	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2
2¼	555	995	1 630	2 530	3 730	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2¼
2½	495	880	1 310	2 215	3 250	4 620	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2½
2¾	445	785	1 180	1 970	2 880	4 080	5 580	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2¾
3	400	710	1 070	1 770	2 580	3 650	4 980	6 630	....	....	....	....	....	....	....	....	....	....	....	....	....	3
3¼	....	650	985	1 610	2 340	3 300	4 500	5 970	7 800	....	....	....	....	....	....	....	....	....	....	....	....	3¼
3½	....	....	910	1 475	2 140	3 010	4 100	5 420	7 080	9 020	....	....	....	....	....	....	....	....	....	....	....	3½
3¾	....	....	....	1 360	1 970	2 770	3 750	4 970	6 450	8 250	10 390	....	....	....	....	....	....	....	....	....	....	3¾
4	....	....	....	1 265	1 830	2 560	3 470	4 600	5 950	7 590	9 550	11 800	....	....	....	....	....	....	....	....	....	4
4¼	....	....	....	....	1 710	2 390	3 230	4 260	5 540	7 030	8 830	10 880	13 270	....	....	....	....	....	....	....	....	4¼
4½	....	....	....	....	1 600	2 230	3 020	3 980	5 150	6 550	8 200	10 100	12 350	14 900	....	....	....	....	....	....	....	4½
4¾	....	....	....	....	....	2 100	2 830	3 730	4 830	6 120	7 680	9 450	11 500	13 850	16 700	....	....	....	....	....	....	4¾
5	....	....	....	....	....	1 980	2 670	3 510	4 540	5 750	7 200	8 850	10 750	12 950	15 600	18 500	....	....	....	....	....	5
5¼	....	....	....	....	....	....	2 520	3 310	4 290	5 410	6 780	8 330	10 120	12 150	14 650	17 300	20 200	....	....	....	....	5¼
5½	....	....	....	....	....	....	2 390	3 140	4 050	5 130	6 400	7 880	9 580	11 500	13 800	16 300	19 100	22 700	....	....	....	5½
5¾	....	....	....	....	....	....	....	2 980	3 850	4 870	6 070	7 450	9 050	10 850	13 050	15 400	18 000	21 400	24 000	....	....	5¾
6	....	....	....	....	....	....	....	2 840	3 660	4 630	5 770	7 080	8 600	10 300	12 350	14 600	17 000	20 300	23 200	26 600	3 0400	6
6¼	....	....	....	....	....	....	....	....	3 500	4 410	5 500	6 740	8 220	9 800	11 750	13 850	16 450	19 300	21 500	25 200	2 8800	6¼
6½	....	....	....	....	....	....	....	....	3 340	4 220	5 250	6 440	7 850	9 350	11 200	13 200	15 400	18 300	20 500	24 000	2 7400	6½
6¾	....	....	....	....	....	....	....	....	....	4 040	5 030	6 150	7 500	8 950	10 700	12 600	14 700	17 500	19 300	22 800	2 6100	6¾
7	....	....	....	....	....	....	....	....	....	3 870	4 820	5 900	7 180	8 550	10 200	12 050	14 000	18 700	18 000	21 800	24 800	7
7½	....	....	....	....	....	....	....	....	....	....	4 450	5 450	6 620	7 880	9 450	11 100	12 850	15 300	17 100	19 800	22 800	7½
8	....	....	....	....	....	....	....	....	....	....	....	....	6 150	7 300	8 730	10 250	11 900	14 150	15 800	18 400	21 000	8
8½	....	....	....	....	....	....	....	....	....	....	....	....	5 730	6 800	8 150	9 550	11 100	13 100	14 700	17 100	19 500	8½
9	....	....	....	....	....	....	....	....	....	....	....	....	....	6 380	7 620	8 950	10 350	12 250	13 700	15 900	18 200	9
9½	....	....	....	....	....	....	....	....	....	....	....	....	....	....	7 150	8 400	9 730	11 550	12 800	14 900	17 000	9½
10	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	7 920	9 180	10 850	12 000	14 100	16 000	10
10½	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	8 700	10 300	11 400	13 300	15 100	10½
11	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	9 750	10 850	12 600	14 300	11
11½	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	10 300	12 000	13 600	11½
12	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	11 400	12 900	12

inches; and M = the mean diameter of the helix in inches; this is found by subtracting the diameter or thickness of the bar from the outside diameter of the spring.

TEST OF SPRINGS NOT IN ACCORDANCE WITH PRECEDING RULES.

15. If it is desired to purchase under these specifications springs in which the maximum fiber stress exceeds that specified in Section 13 (*a*), the tests shall be made as specified in Section 7 except that the maximum test load to be applied in determining the properties specified in Sections 7 (*a*) and (*d*) shall not be sufficient to compress the spring solid, but shall be the load which corresponds to a fiber stress of 90,000 lb. per sq. in., as determined by Eq. 1.

TABLE TO FACILITATE CALCULATIONS.

16. Table I is arranged to facilitate the calculations necessary to determine whether a spring can be tested in accordance with the specifications without exceeding the stress given in Section 13 (*a*). The table shows the loads at which springs of various sizes are stressed to 90,000 lb. per sq. in. These are the test loads to be used for springs tested in accordance with Section 15. In testing in accordance with Section 7 (*a*) the load given in Table I for the given size of spring shall not be exceeded, unless with this load the spring is compressed solid.

STANDARD SPECIFICATIONS
FOR
ELLIPTICAL STEEL SPRINGS FOR RAILWAYS[1]

Serial Designation: A 62 - 16

These specifications are issued under the fixed designation A 62; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ADOPTED, 1916.

Scope.

1. These specifications cover all elliptic steel springs for suspension, draft and buffer purposes for locomotives, tenders and cars.

Basis of Purchase.

2. (*a*) The springs shall be made of carbon-steel bars conforming to the requirements of the Standard Specifications for Carbon-Steel Bars for Railway Springs (Serial Designation: A 14) of the American Society for Testing Materials,[2] unless otherwise specified.

(*b*) If carbon-steel bars with special silicon requirements or alloy-steel bars are specified, the manufacturer and the purchaser shall agree upon the type and grade of the bars to be used; in which case the bars shall conform, for the respective types, to the Standard Specifications for Carbon-Steel Bars for Railway Springs with Special Silicon Requirements (Serial Designation: A 68),[3] the Standard Specifications for Silico-Manganese-Steel Bars for Railway Springs (Serial Designation: A 59),[4] or the Standard Specifications for Chrome-Vanadium-Steel Bars for Railway Springs (Serial Designation: A 60),[5] of the American Society for Testing Materials.

(*c*) The bands of the springs shall be made of wrought iron conforming to the requirements of the Standard Specifications for Refined Wrought-Iron Bars (Serial Designation: A 41) of the American Society for Testing Materials;[6] or if agreed upon, they may be made of "dead-soft" open-hearth steel, the carbon content of which shall not exceed 0.15 per cent. Bands of special design, subject to agreement between the manufacturer and the purchaser, may be made of steel castings conforming to

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

[2] See p. 149. [3] See p. 152. [4] See p. 157. [5] See p. 159. [6] See p. 389.

the requirements of the Standard Specifications for Steel Castings, Class B, Soft Grade (Serial Designation: A 27), of the American Society for Testing Materials.[1]

(*d*) Drillings for chemical analysis shall be taken from pieces sheared from the bars during the process of manufacture, and not from a finished spring, unless otherwise agreed upon.

(*e*) In determining the loaded height and loaded length of the springs, the "compression" method of Section 7 shall be used, unless the "release" method of Section 8 is specified.

CHEMICAL PROPERTIES AND TESTS

Check Analyses.

3. (*a*) An analysis may be made by the purchaser from a sample representing each size of spring steel involved. The chemical composition thus determined shall conform to the requirements specified in Section 2 (*a*) or (*b*).

(*b*) Drillings for analysis shall be taken from the unworked portion of the bars and shall represent the full cross-section after rejecting any decarburized material.

(*c*) In case of dispute, check and arbitration analyses of carbon steel shall be made in accordance with the Standard Methods of Chemical Analysis of Plain Carbon Steel (Serial Designation: A 33) of the American Society for Testing Materials,[2] the carbon being determined by the "direct-combustion" method; and of alloy steel, in accordance with the Standard Methods of Chemical Analysis of Alloy Steels (Serial Designation: A 55) of the American Society for Testing Materials.[3]

WORKMANSHIP

Inspection.

4. The purchaser or his representative may examine all springs in each lot for workmanship and general dimensions.

Workmanship

5. (*a*) The springs shall be submitted for inspection complete in the condition required by the drawings, and shall conform to these drawings with the permissible variations specified in this Section and Sections 7 or 8. Dimensions which affect the contour only and do not affect the interchange or service of the springs need only be approximated.

(*b*) The springs shall have the leaves properly graduated in length, properly bent, and fitted to reasonably true circular arcs.

(*c*) The bands of the springs shall not vary from the specified dimensions more than $\frac{1}{16}$ in. in width and $\frac{1}{32}$ in. in thickness of straps, nor more than $\frac{1}{8}$ in. in width across the spring.

[1] See p. 231. [2] See p. 276. [3] See p. 300.

PHYSICAL PROPERTIES AND TESTS

Number of Tests.

6. (*a*) From each lot of springs which has met the requirements of Section 5, the purchaser or his representative may select for physical tests at least 25 per cent, to be tested in accordance with the "compression" method of Section 7—or if specified, in accordance with the "release" method of Section 8—and the appendix.

(*b*) If any of the springs representing a lot fail to meet the requirements as to physical properties specified in Section 7 or Section 8 as required, but at least half of the springs representing a lot do meet these requirements, each spring of the lot shall be tested and those which meet the requirements shall be accepted. If more than half of the springs representing a lot fail to meet the requirements specified in Section 7 or Section 8 as required, the lot represented will be rejected.

Physical Tests: Compression Method.

7. When the "compression" method is to be used, the properties specified in Paragraphs (*a*), (*b*) and (*c*), modified if necessary to conform to the requirements of the appendix, shall be determined, in the order specified. The spring shall not be rapped or otherwise disturbed during the test. The ends of half-elliptic springs shall be supported on roller or swing bearings.

(*a*) *Free Height.*—The free height is the height of the spring after a test load of $1\frac{1}{2}$ times the specified working load has been applied and fully released.

(*b*) *Loaded Height and Loaded Length.*—The loaded height and loaded length are respectively the height and length when the specified working load is applied. The load shall be applied gradually and in such a way that the specified working load shall not be exceeded. If it is exceeded, the load shall be released to not more than one-half the specified working load and then increased to the specified working load. The loaded height shall not be less, but may be $\frac{3}{8}$ in. more than that specified. The loaded length shall not vary more than $\frac{1}{4}$ in. from that specified.

(*c*) *Permanent Set.*—The permanent set is the difference, if any, between the free height and the height after the test load of $1\frac{1}{2}$ times the specified working load has again been applied and fully released. The following two requirements shall be met:

(1) The permanent set shall not exceed $\frac{1}{32}$ in.;

(2) If there is any permanent set not exceeding $\frac{1}{32}$ in. the difference between the free height and the height after

the test load of $1\frac{1}{2}$ times the specified working load has been applied and fully released two additional times, shall not be greater than the permanent set first measured.

Physical Tests: Release Method.

8. When the "release" method is specified, the properties specified in Paragraphs (*a*), (*b*) and (*c*), modified if necessary to conform to the requirements of the appendix, shall be determined in the order specified. The spring shall not be rapped or otherwise disturbed during the test. The ends of half-elliptic springs shall be supported on roller or swing bearings.

(*a*) *Free Height.*—The free height is the height of the spring after a test load of $1\frac{1}{2}$ times the specified working load has been applied and fully released.

(*b*) *Loaded Height and Loaded Length.*—The loaded height and loaded length are respectively the height and length when a test load of $1\frac{1}{2}$ times the specified working load has been applied and is slowly released to the specified working load. If released to less than the specified working load, the load shall again be raised to $1\frac{1}{2}$ times the specified working load and then released to the specified working load. The loaded height shall not be more, but may be $\frac{3}{8}$ in. less than that specified. The loaded length shall not vary more than $\frac{1}{4}$ in. from that specified.

(*c*) *Permanent Set.*—The permanent set is the difference, if any, between the free height and the height after the test load of $1\frac{1}{2}$ times the specified working load has again been applied and fully released. The following two requirements shall be met:

(1) The permanent set shall not exceed $\frac{1}{32}$ in.;

(2) If there is any permanent set not exceeding $\frac{1}{32}$ in., the difference between the free height and the height after the test load of $1\frac{1}{2}$ times the specified working load has been applied and fully released two additional times, shall not be greater than the permanent set first measured.

MARKING

Marking.

9. (*a*) The name or brand of the manufacturer, the year and month of manufacture, and if specified, the purchaser's class number, shall be legibly stamped on each spring at a place not detrimental to the life or service of the spring.

(*b*) Any stamping by the inspector shall be so placed as not to be detrimental to the life or service of the spring.

INSPECTION AND REJECTION

Inspection.

10. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser

is being performed, to all parts of the manufacturer's works which concern the manufacture of the springs ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the springs are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manfacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection.

11. Unless otherwise specified, any rejection based on tests made in accordance with Section 3 shall be reported within five working days from the receipt of samples.

Rehearing.

12. Samples tested in accordance with Section 3, which represent rejected springs, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

Reworking.

13. Any springs which fail to meet the requirements as to dimensions or physical tests may be again submitted after being reworked.

APPENDIX.

Test Fiber Stress.

14. (*a*) The properties and methods of testing specified in Sections 7 and 8, have been established for carbon-steel springs on the assumption that the maximum fiber stress under test shall not exceed 127,500 lb. per sq. in.[1]

(*b*) For alloy-steel springs practice has not been sufficiently well established to enable definite fiber stresses to be given. Unless otherwise agreed upon by the manufacturer and the purchaser, alloy-steel springs shall be tested under the conditions as to fiber stress specified for carbon-steel springs.

Relation Between Fiber Stress and Load.

15. To find the maximum loads under which the conditions of Section 14 (*a*) are fulfilled, the following formula shall be used:

$$P = \frac{2Snbh^2}{3L} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where P = the load in pounds; S = the stress of the most strained fiber in pounds per square inch; n = the number of plates in half-elliptic springs, or half the number of plates in full-elliptic springs; b = the width of each plate in inches; h = the thickness of each plate in inches; and L = the distance between supports, in inches, when the spring is loaded.

Test of Springs not in Accordance with Preceding Rules.

16. If it is desired to purchase under these specifications springs in which the maximum fiber stress exceeds that specified in Section 14 (*a*), the tests shall be made as specified in Sections 7 or 8 except that the test load to be applied shall not be 1½ times the specified working load, but shall be the load which corresponds to a fiber stress of 127,500 lb. per sq. in., as determined by Eq. 1.

[1] This stress is given solely as a limiting stress not to be exceeded in testing by the methods covered by the specifications. It is not intended as a guide in the design of springs, as the proper working fiber stress will depend on the class and design of the spring and on the service for which it is intended.

TESTS OF SPRINGS FOR WHICH NO WORKING LOAD IS SPECIFIED.

17. If springs are ordered to free height and length only, and no working load and no loaded dimensions are specified,

TABLE I.—TEST LOADS FOR ELLIPTICAL SPRINGS, IN POUNDS PER INCH OF EFFECTIVE WIDTH, WHICH WILL CORRESPOND TO A MAXIMUM FIBER STRESS OF 127,500 LB. PER SQ. IN.

Length of Spring in.	Thickness of Plate, in.						
	3/16	1/4	5/16	3/8	7/16	1/2	9/16
20	150	265	...	...	...	...	...
22	136	241	377	...	...	...	...
24	125	221	345	497	...	...	...
26	115	204	319	460	625	...	...
28	107	190	296	427	581	760	...
30	100	177	277	398	543	707	896
32	...	166	259	374	509	665	840
34	...	156	244	351	479	625	791
36	...	148	230	332	452	590	748
38	...	140	218	314	429	560	708
40	...	133	208	298	407	531	673
42	...	126	198	284	388	506	640
44	...	...	189	272	370	483	612
46	...	...	180	260	354	462	585
48	...	...	...	249	339	443	561
50	...	...	...	239	325	425	538
52	...	...	...	...	313	409	518
54	...	...	...	...	302	394	499
56	...	...	...	...	...	380	481
58	...	...	...	...	...	366	465
60	...	...	...	...	...	354	450

the tests specified in Sections 7 or 8 shall be made, using instead of the "specified working load" the load which corresponds to a fiber stress of 75,000 lb. per sq. in., as determined by Eq. 1.

TABLE TO FACILITATE CALCULATIONS.

18. Table I is arranged to facilitate the calculations necessary to determine whether a spring can be tested in accordance with the specifications without exceeding the stress given in Section 14 (*a*). The table shows, for various lengths and for various thicknesses of plate, the loads per inch of effective width of spring corresponding to a fiber stress of 127,500 lb. per sq. in. These are the maximum allowable test loads, and shall not be exceeded in any tests.

The loads are given per inch of effective width of spring. The effective width of spring is understood to mean the width of the individual plate multiplied by the number of plates as defined in Section 15. Consequently the total load in pounds for any spring is found by multiplying the value from Table I by the product of the width of plate into the number of plates.

STANDARD SPECIFICATIONS
FOR
CARBON-STEEL AND ALLOY-STEEL BLOOMS, BILLETS AND SLABS FOR FORGINGS[1]

Serial Designation: A 17 – 21

These specifications are issued under the fixed designation A 17; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ADOPTED, 1913; REVISED, 1918, 1921.

These specifications were approved August 20, 1924, as "Tentative American Standard" by the American Engineering Standards Committee.

Definition of Term.

1. The term "billet" is used in these specifications to include blooms, billets and slabs.

Scope.

2. (*a*) These specifications cover billets of carbon and alloy steel. Eight types of steel are covered, one type of carbon and seven types of alloy steels, classification by type being made according to the chemical composition, other than carbon.

(*b*) Each type of steel is sub-divided into grades according to the carbon content. There are eight grades of carbon steel and seven grades of each type of alloy steel.

(*c*) The billets are further divided into two classes, designated Classes I and II. Class I is the standard for all types and grades; and Class II is a special class applicable to Grades Nos. 4 to 8, inclusive, in Type A, and to Grades Nos. 14 to 17, inclusive, in all other types. Class II differs from Class I in the method of sampling for chemical analysis and in chemical requirements.

Basis of Purchase.

3. Billets shall be purchased as semi-finished rolled or forged material.

MANUFACTURE

Process.

4. The steel shall be made by either or both the following processes: open-hearth or electric-furnace.

Discard.

5. A sufficient discard shall be made from each ingot to secure freedom from injurious piping and undue segregation.

Reduction from Ingot.

6. Unless otherwise specified, the billets shall be made from ingots of at least four times the cross-sectional area of the billet.

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

7. The steel shall conform to the following requirements as to chemical composition for type and grade:

(*a*) *Type.*—The types of steel shall be as indicated in Table I.

(*b*) *Grade.*—The carbon ranges for the various grades shall be as follows for carbon and alloy steel:

Carbon Steel—Type A.		Alloy Steels—Types B to H, incl.	
Grade.	Carbon, Per Cent.	Grade.	Carbon, Per Cent.
1	0.05 – 0.15	11	0.10 – 0.20
2	0.15 – 0.25	12	0.15 – 0.25
3	0.20 – 0.30	13	0.20 – 0.30
4	0.25 – 0.40	14	0.25 – 0.38
5	0.30 – 0.45	15	0.30 – 0.43
6	0.35 – 0.50	16	0.35 – 0.50
7	0.40 – 0.55	17	0.45 – 0.60
8	0.45 – 0.60		

Note 1. When the steel is to be used for case-hardening purposes, the manganese should be specified not to exceed 0.50 per cent. When the minimum carbon specified is 0.35 per cent or over, the manganese range may be specified 0.30 – 0.60 per cent.

Note 2. In selecting billets for making forgings of Classes K, L and M, as defined in the Standard Specifications for Carbon-Steel and Alloy-Steel Forgings (Serial Designation: A 18) of the American Society for Testing Materials,[1] it is suggested that the use of steel with a relatively high carbon content will permit the use of a high draw-back temperature and thus put the steel in its best physical condition for service, shock and similar conditions.

Ladle Analyses.

8. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements specified in Section 7. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 7.

Check Analyses.

9. (*a*) *Class I.*—For billets of Class I, an analysis may be made by the purchaser from one billet representing each melt. The chemical composition thus determined shall conform to the requirements specified in Section 7. Drillings for analysis shall be taken with a $\frac{5}{8}$-in. drill, parallel to the axis of the ingot as cast, at any point midway between the center and surface of the billet.

(*b*) *Class II.*—For billets of Class II, the purchaser or his representative may select one top-cut billet from which to make check analyses to represent each melt. Two sets of drillings

[1] See p. 179.

shall be taken from the top face of this billet at points on the same diagonal of the billet. The drillings shall be taken with a $\frac{5}{8}$-in. drill parallel to the axis of the ingot as cast. The distance from the center of the billet to the drilling points shall be respectively 15 and 80 per cent of the length of the half diagonal of the billet.

(*c*) From the drillings taken at the 80-per-cent point a complete analysis may be made. The chemical composition thus determined shall conform to the requirements specified in Section 7.

(*d*) From the drillings taken at the 15-per-cent point a carbon determination may be made. The difference between the carbon content of the drillings from the 15-per-cent point

TABLE I.—TYPES OF STEEL.

ELEMENTS CONSIDERED.	TYPE.							
	A.	B.	C.	D.	E.	F.	G.	H.
	Carbon Steel.	Nickel Steel.	Chrome-Nickel Steel.				Chrome Steel.	Chrome-Vanadium Steel.
			1.00 - 1.50 per cent Ni.	1.50 - 2.00 per cent Ni.	2.75 - 3.25 per cent Ni.	3.00 min. per cent Ni.		
Manganese, per cent...	0.50 - 0.80	0.50 - 0.80	0.50 - 0.80	0.30 - 0.60	0.45 - 0.75	0.30 - 0.60	0.30 - 0.60	0.50 - 0.80
Phosphorus, max., per cent...	0.045	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Sulfur, max., per cent...	0 050	0.045	0.045	0.045	0.045	0.045	0.045	0.045
Nickel, per cent...	.....	not under 3.00	1.00 - 1.50	1.50 - 2.00	2.75 - 3.25	not under 3.00	.....	.....
Chromium, per cent...	.....	.....	0.45 - 0.75	0.90 - 1.25	0.60 - 0.95	not under 1 00	0.60 - 0.90	0.80 - 1.10
Vanadium, min., per cent...	.....	.....	.....	.....	.....	.....	.....	0 15

and that of the drillings from the 80-per-cent point, expressed as a percentage of the latter, shall not exceed the following values:

(1) For billets 15 in. or under in thickness, 15 per cent;
(2) For billets over 15 in. in thickness, 20 per cent.

(*e*) If in any melt the drillings taken in accordance with Paragraph (*b*) do not conform to the requirements of Paragraph (*d*), additional drillings may be taken in a similar manner after making a further top discard from the material from each

ingot of at least 10 per cent of the original ingot weight. The results of this analysis shall conform to the requirements of Paragraph (*d*); otherwise, the melt represented shall be rejected.

WORKMANSHIP AND FINISH

Chipping.

10. (*a*) Billets may be chipped to remove surface defects, provided that the depth of chipping does not exceed $\frac{1}{16}$ in. for each inch of dimension concerned, up to a maximum depth of $\frac{3}{4}$ in., and provided that the width of the chipping is at least four times its greatest depth; except that in the case of slabs where the width is at least twice the thickness, the depth of chipping on the wide surfaces may exceed this allowance by 50 per cent, up to a maximum depth of $\frac{3}{4}$ in.

(*b*) In special cases, particularly large alloy-steel billets where it is necessary and is not injurious, greater depth of chipping may be permitted by special agreement between the manufacturer and the purchaser.

Finish.

11. The billets shall be free from injurious defects and shall have a workmanlike finish.

MARKING

Marking.

12. (*a*) The melt number shall be legibly stamped on each billet 6 in. or over in thickness, and on billets of smaller section when so specified.

(*b*) For billets of Class I, the top end of all top-cut billets 6 in. or over in thickness shall be legibly hot-stamped with the letter "T" and marked with paint.

(*c*) For billets of Class II, the top ends of the top, second, third, and following cut billets from each ingot shall be legibly hot-stamped with the letters "A", "B", "C", etc., to show the position of the billet in the ingot, and marked with paint.

INSPECTION AND REJECTION

Inspection.

13. (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the billets ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the billets are being furnished in accordance with these specifications. Tests and inspection at the place of manufacture shall be made prior to shipment.

(*b*) The purchaser may make the tests to govern the acceptance or rejection of billets in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

(*c*) All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection.

14. (*a*) Unless otherwise specified, any rejections based on tests made in accordance with Section 13 (*b*) shall be reported within five working days from the receipt of samples.

(*b*) Billets which show injurious defects while being finished by the purchaser will be rejected, and the manufacturer shall be notified.

Rehearing.

15. Samples tested in accordance with Section 13 (*b*), which represent rejected billets, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

STANDARD SPECIFICATIONS
FOR
CARBON-STEEL AND ALLOY-STEEL FORGINGS[1]

Serial Designation: A 18 – 27

These specifications are issued under the fixed designation A 18; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ADOPTED, 1901; REVISED, 1905, 1914, 1916, 1918, 1921, 1927.

Scope.

1. (*a*) These specifications cover the various classes of carbon-steel and alloy-steel forgings now commonly used and not covered by other existing specifications of the American Society for Testing Materials.

(*b*) The purposes for which these classes are frequently used are as follows:

Class A, for forgings which may be welded or case-hardened;

Class B, for mild-steel forgings for structural purposes, for minor ship fittings, etc.;

Class C, for mild-steel forgings for structural purposes, for ships, etc.;

Classes D, E, F, G, H and I, for various machinery forgings, choice depending upon design and upon the stresses and services to be imposed.

Classes K, L and M, for various machinery forgings, choice depending upon design and upon the stresses and services to be imposed, and upon the character of machining operations to be done.

MANUFACTURE

Process.

2. The steel shall be made by either or both the following processes: open-hearth or electric-furnace.

Discard.

3. A sufficient discard shall be made from each ingot to secure freedom from injurious piping and undue segregation.

Prolongations for Tests.

4. Unless otherwise specified, for test purposes at least 20 per cent of the forgings shall be provided with prolongations or, at the manufacturer's option, a forging may be selected.

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

Boring.

5. If boring is specified, the diameter of the hole shall be at least 20 per cent of the maximum outside diameter or thickness of the forging, exclusive of collars and flanges.

Heat Treatment.

6. Heat treatment, if required, shall consist of either annealing or quenching and tempering, as specified.

(*a*) The procedure to be followed in annealing shall consist in allowing the objects, immediately after forging, to cool to a temperature below the critical range, under suitable conditions to prevent injury by too rapid cooling. They shall then be uniformly reheated to the proper temperature to refine the grain (a group thus reheated being known as an "annealing charge"), and allowed to cool uniformly.

(*b*) The procedure to be followed in quenching and tempering shall consist in allowing the objects, immediately after forging, to cool to a temperature below the critical range, under suitable conditions to prevent injury by too rapid cooling. They shall then be uniformly reheated to the proper temperature to refine the grain (a group thus reheated being known as a "quenching charge"), and quenched in some medium under substantially uniform conditions for each quenching charge. Finally, they shall be uniformly reheated to the proper temperature for tempering or "drawing back" (a group thus reheated being known as a "tempering charge"), and allowed to cool uniformly.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

7. (*a*) The steel shall conform to the following requirements as to chemical composition:

Elements Considered	Classes				
	A	B, C, D, E, F, G	H, I	K, L	M
Manganese, per cent	0.30–0.55	0.40–0.80	0.40–0.80	.....	.....
Phosphorus, per cent:					
Acid	not over 0.05	not over 0.05	not over 0.04	not over 0.05	not over 0.04
Basic	" " 0.05	" " 0.05	" " 0.04	" " 0.04	" " 0.04
Sulfur, per cent	" " 0.05	" " 0.05	" " 0.05	" " 0.05	" " 0.05
Nickel, per cent	.....	.....	not under 3.00	.....	.....

(*b*) The composition of alloy steel, other than phosphorus and sulfur, to be used in forgings of Classes K, L and M, shall be agreed upon by the manufacturer and the purchaser.

Ladle Analyses.

8. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese and the elements specified in Section 7. This analysis shall be made from a

test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 7.

Check Analyses.

9. An analysis may be made by the purchaser from a forging representing each melt. The chemical composition thus determined shall conform to the requirements specified in Section 7. Drillings for analysis may be taken from the forging or from a full-size prolongation of the same, at any point midway between the center and surface of solid forgings, and at any point midway between the inner and outer surfaces of the wall of bored forgings; or turnings may be taken from a test specimen.

PHYSICAL PROPERTIES AND TESTS

Tension Tests.

10. (*a*) The forgings shall conform to the requirements as to tensile properties specified in Tables I, II and III.

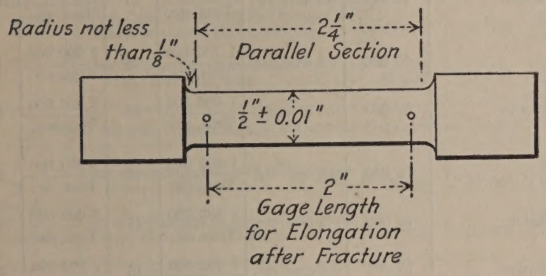
Radius not less than 1/8"
2 1/4"
Parallel Section
1/2" ± 0.01"
2"
Gage Length for Elongation after Fracture
Note:-The Gage Length, Parallel Section, and Fillets shall be as Shown, but the Ends may be of any Shape to fit the Holders of the Testing Machine in such a Way that the Load shall be axial.

FIG. 1.

(*b*) The classification by size of the forging shall be determined by the specified diameter or thickness which governs the size of the prolongation from which the test specimen is taken.

(*c*) The yield point shall be determined by the drop of the beam of the testing machine.

(*d*) The elastic limit called for by these specifications shall be determined by an extensometer reading to 0.0002 in. The extensometer shall be attached to the specimen at the gage marks and not to the shoulders of the specimen nor to any part of the testing machine. When the specimen is in place and the extensometer attached, the testing machine shall be operated so as to increase the load on the specimen at a uniform rate. The observer shall watch the elongation of the specimen as shown by the extensometer and shall note, for this determination, the load at which the rate of elongation shows a sudden increase. The extensometer shall then be removed from the specimen, and the test continued to determine the tensile strength.

(*e*) Tests of forgings shall be made only after final treatment.

Tension Test Specimens.

11. (*a*) Tension test specimens shall be taken from a full-size prolongation of any forging. For forgings with large ends or collars the prolongation may be of the same cross-section as that of the

TABLE I.—TENSILE PROPERTIES (CLASSES A TO F, INCLUSIVE).

FOR FORGINGS WHOSE MAXIMUM OUTSIDE DIAMETER OR OVER-ALL THICKNESS IS NOT OVER 20 IN.

Class	Size, Outside Diameter or Over-all Thickness	Tensile Strength, min. (except Class A), lb. per sq. in.	Yield Point, min., lb. per sq. in.	Elongation in 2 in., min., per cent		Reduction of Area, min., per cent	
				Inverse Ratio	Not under	Inverse Ratio	Not under
A Untreated	All sizes..	47 000 to 60 000	0.5 tens. str.	1 500 000 / Tens. str.	..	2 500 000 / Tens. str.	..
B Untreated	Not over 12 in	60 000	0.5 tens. str.	1 550 000 / Tens. str.	22	2 400 000 / Tens. str.	35
	Over 12 to 20 in., inclusive	60 000	0.5 tens. str.	1 480 000 / Tens. str.	21	2 220 000 / Tens. str.	32
C Annealed	Not over 12 in	60 000	0.5 tens. str.	1 700 000 / Tens. str.	25	2 700 000 / Tens. str.	38
	Over 12 to 20 in., inclusive	60 000	0.5 tens. str.	1 600 000 / Tens. str.	24	2 520 000 / Tens. str.	36
D Untreated	Not over 8 in	75 000	0.5 tens. str.	1 600 000 / Tens. str.	18	2 200 000 / Tens. str.	24
	Over 8 to 12 in., inclusive	75 000	0.5 tens. str.	1 500 000 / Tens. str.	17	2 000 000 / Tens. str.	22
	Over 12 to 20 in., inclusive	75 000	0.5 tens. str.	1 400 000 / Tens. str.	16	1 800 000 / Tens. str.	20
E Annealed	Not over 8 in	75 000	0.5 tens. str.	1 800 000 / Tens. str.	20	2 800 000 / Tens. str.	33
	Over 8 to 12 in., inclusive	75 000	0.5 tens. str.	1 725 000 / Tens. str.	19	2 640 000 / Tens. str.	31
	Over 12 to 20 in., inclusive	75 000	0.5 tens. str.	1 650 000 / Tens. str.	18	2 400 000 / Tens. str.	29
F Annealed	Not over 8 in	80 000	0.5 tens. str.	1 800 000 / Tens. str.	20	2 800 000 / Tens. str.	32
	Over 8 to 12 in., inclusive	80 000	0.5 tens. str.	1 725 000 / Tens. str.	19	2 640 000 / Tens. str.	30
	Over 12 to 20 in., inclusive	80 000	0.5 tens. str.	1 650 000 / Tens. str.	18	2 400 000 / Tens. str.	28

forging back of the large end or collar. Specimens may be taken from the forging itself with a hollow drill, if approved by the purchaser.

(*b*) The axis of the specimen shall be located at any point midway between the center and surface of solid forgings, and at any point midway between the inner and outer surfaces of the wall of

bored forgings, and shall be parallel to the axis of the forging in the direction in which the metal is most drawn out.

(*c*) The specimens shall conform to the dimensions shown in Fig. 1. The ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial.

TABLE II.—TENSILE PROPERTIES (CLASSES G, H, AND I).

Class	Size	Tensile Strength, min., lb. per sq. in.	Elastic Limit, min., lb. per sq. in.	Elongation in 2 in., min., per cent.		Reduction of Area, min., per cent	
				Inverse Ratio	Not under	Inverse Ratio	Not under
FOR FORGINGS WHOSE MAXIMUM OUTSIDE DIAMETER OR THICKNESS IS NOT OVER 10 IN. WHEN SOLID, AND NOT OVER 20 IN. WHEN BORED							
G Quenched and Tempered	Up to 4 in. in outside diameter or thickness, 2-in. max. wall	90 000	55 000	2 100 000 / Tens. str.	20.5	4 000 000 / Tens. str.	39
	Over 4 to 7 in. in outside diameter or thickness, 3½-in. max. wall	85 000	50 000	2 000 000 / Tens. str.	20.5	3 800 000 / Tens. str.	39
	Over 7 to 10 in. in outside diameter or thickness, 5-in. max. wall	85 000	50 000	1 900 000 / Tens. str.	19.5	3 600 000 / Tens. str.	37
	Outside diameter or thickness not over 20 in., 5 to 8-in. wall	82 500	48 000	1 800 000 / Tens. str.	19	3 400 000 / Tens. str.	36
FOR FORGINGS WHOSE MAXIMUM OUTSIDE DIAMETER OR OVER-ALL THICKNESS IS NOT OVER 20 IN.							
H Nickel Steel, Annealed	Outside diameter or over-all thickness not over 12 in	80 000	50 000	2 000 000 / Tens. str.	22	3 600 000 / Tens. str.	40
	Outside diameter or over-all thickness over 12 to 20 in., inclusive	80 000	50 000	1 900 000 / Tens. str.	21	3 400 000 / Tens. str.	38
FOR FORGINGS WHOSE MAXIMUM OUTSIDE DIAMETER OR THICKNESS IS NOT OVER 10 IN. WHEN SOLID, AND NOT OVER 20 IN. WHEN BORED.							
I Nickel Steel, Quenched and Tempered	Up to 4 in. in outside diameter or thickness, 2-in. max. wall	100 000	70 000	2 200 000 / Tens. str.	20	4 500 000 / Tens. str.	41
	Over 4 to 7 in. in outside diameter or thickness, 3½-in. max. wall	100 000	65 000	2 100 000 / Tens. str.	20	4 300 000 / Tens. str.	41
	Over 7 to 10 in. in outside diameter or thickness, 5-in. max. wall	90 000	60 000	2 000 000 / Tens. str.	20	4 100 000 / Tens. str.	41
	Outside diameter or thickness not over 20 in., 5 to 8-in. wall	85 000	55 000	1 900 000 / Tens. str.	20	3 900 000 / Tens. str.	41

Number of Tests.

12. Unless otherwise specified by the purchaser, tests shall be made as follows:

(*a*) For untreated forgings, one tension test shall be made from each melt.

(*b*) For annealed forgings, one tension test shall be made from each annealing charge. If more than one melt is represented in an annealing charge, one tension test shall be made from each melt.

(*c*) For quenched and tempered forgings, one tension test shall

be made from each tempering charge. If more than one quenching charge is represented in a tempering charge, one tension test shall be made from each quenching charge. If more than one melt is rep-

TABLE III.—TENSILE PROPERTIES (CLASSES K, L AND M).

FOR FORGINGS WHOSE MAXIMUM OUTSIDE DIAMETER OR THICKNESS IS NOT OVER 10 IN. WHEN SOLID, AND NOT OVER 20 IN. WHEN BORED.

Class	Size	Tensile Strength, lb. per sq. in.	Elastic Limit, min., lb. per sq. in.	Elongation in 2 in., min., per cent	Reduction of Area, min., per cent
K Alloy Steel, Quenched and Tempered	Up to 2 in. in outside diameter or thickness, 1-in. max. wall	95 000 – 115 000	70 000	20	50
	Over 2 to 4 in. in outside diameter or thickness, 2-in. max. wall	90 000 – 110 000	65 000	20	50
	Over 4 to 7 in. in outside diameter or thickness, 3½-in. max. wall	90 000 – 110 000	65 000	20	50
	Over 7 to 10 in. in outside diameter or thickness, 5-in. max. wall	90 000 – 110 000	65 000	20	50
	Outside diameter or thickness not over 20 in., 5 to 8-in. wall	85 000 – 105 000	60 000	20	50
L Alloy Steel, Quenched and Tempered	Up to 2 in. in outside diameter or thickness, 1-in. max. wall	105 000 – 125 000	80 000	20	50
	Over 2 to 4 in. in outside diameter or thickness, 2-in. max. wall	100 000 – 120 000	75 000	20	50
	Over 4 to 7 in. in outside diameter or thickness, 3½-in. max. wall	100 000 – 120 000	75 000	20	50
	Over 7 to 10 in. in outside diameter or thickness, 5-in. max. wall	100 000 – 120 000	75 000	18	45
	Outside diameter or thickness not over 20 in., 5 to 8-in. wall	95 000 – 115 000	70 000	18	45
		Minimum.			
M Alloy Steel, Quenched and Tempered	Up to 2 in. in outside diameter or thickness, 1-in. max. wall	125 000	105 000	16	50
	Over 2 to 4 in. in outside diameter or thickness, 2-in. max. wall	115 000	95 000	16	45
	Over 4 to 7 in. in outside diameter or thickness, 3½-in. max. wall	110 000	85 000	16	45
	Over 7 to 10 in. in outside diameter or thickness, 5-in. max. wall	100 000	75 000	18	45
	Outside diameter or thickness not over 20 in., 5 to 8-in. wall	100 000	70 000	18	45

resented in a quenching charge, one tension test shall be made from each melt.

(*d*) If more than one class of forgings by size is represented in any lot, one tension test from a forging of each class by size shall be made as specified in Sections 10 and 11.

(*e*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*f*) If the percentage of elongation of any test specimen is less than that specified in Section 10 (*a*) and any part of the fracture is

more than $\frac{3}{4}$ in. from the center of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

Retests. 13. If the results of the physical tests of any test lot of forgings do not conform to the requirements specified, the manufacturer may re-treat such lot one or more times and retests shall be made as specified in Section 12.

WORKMANSHIP AND FINISH

Workmanship. 14. The forgings shall conform to the sizes and shapes specified by the purchaser. When centered, 60-deg. centers with clearance drilled for points shall be used.

Finish. 15. The forgings shall be free from injurious defects and shall have a workmanlike finish.

MARKING

Marking. 16. Identification marks shall be legibly stamped on each forging and on each test specimen. The purchaser shall indicate the location of such identification marks.

INSPECTION AND REJECTION

Inspection. 17. (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the forgings ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the forgings are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

(*b*) The purchaser may make the tests to govern the acceptance or rejection of the forgings in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

Rejection. 18. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 17 (*b*) shall be reported within five working days from the receipt of samples.

(*b*) Forgings which show injurious defects while being finished by the purchaser will be rejected, and the manufacturer shall be notified.

Rehearing. 19. Samples tested in accordance with Section 17 (*b*), which represent rejected forgings, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

STANDARD SPECIFICATIONS FOR QUENCHED-AND-TEMPERED CARBON-STEEL AXLES, SHAFTS, AND OTHER FORGINGS FOR LOCOMOTIVES AND CARS[1]

Serial Designation: A 19 – 27

These specifications are issued under the fixed designation A 19; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ADOPTED, 1911; REVISED, 1912, 1914, 1916, 1918, 1921, 1927.

Scope.

1. When used for forgings for locomotives, these specifications cover quenched-and-tempered carbon-steel driving axles, engine and trailing-truck axles, main and side rods, straps, crank pins and piston rods.

MANUFACTURE

Process.

2. The steel shall be made by either or both the following processes: open-hearth or electric-furnace.

Discard.

3. A sufficient discard shall be made from each ingot to secure freedom from injurious piping and undue segregation.

Prolongations for Tests.

4. Unless otherwise specified, for test purposes at least 20 per cent of the forgings shall be provided with prolongations or, at the manufacturer's option, a forging may be selected.

Boring.

5. (*a*) Unless otherwise specified by the purchaser, all forgings over 7 in. in diameter shall be bored, and all axles, shafts and similar forgings shall be rough-turned all over. The boring shall be done before quenching.

(*b*) If boring is specified, the diameter of the hole shall be at least 20 per cent of the maximum outside diameter or thickness of the forging, exclusive of collars and flanges.

Heat Treatment.

6. The procedure to be followed in quenching and tempering shall consist in allowing the objects, immediately after forging, to cool to a temperature below the critical range, under suitable conditions to prevent injury by too rapid cooling. They shall then be uniformly reheated to the proper temperature to refine the grain

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

(a group thus reheated being known as a "quenching charge"), and quenched in some medium under substantially uniform conditions for each quenching charge. Finally, they shall be uniformly reheated to the proper temperature for tempering or "drawing back" (a group thus reheated being known as a "tempering charge"), and allowed to cool uniformly.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

7. The steel shall conform to the following requirements as to chemical composition:

Carbon	First Class by Size	0.25 – 0.60 per cent
	Second " " "	0.35 – 0.60 "
	Third " " "	0.35 – 0.65 "
	Fourth " " "	0.35 – 0.70 "
Manganese		0.40 – 0.70 "
Phosphorus		not over 0.05 "
Sulfur		" " 0.05 "

Ladle Analyses.

8. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements specified in Section 7. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 7.

Check Analyses.

9. (*a*) An analysis may be made by the purchaser from a forging representing each melt. The chemical composition thus determined shall conform to the requirements specified in Section 7. Drillings for analysis may be taken from the forging or from a full-size prolongation of the same, at any point midway between the center and surface of solid forgings, and at any point midway between the inner and outer surfaces of the wall of bored forgings; or turnings may be taken from a test specimen.

(*b*) In addition to the complete analysis specified in Paragraph (*a*), a phosphorus determination may be made by the purchaser from each broken tension test specimen. The phosphorus content thus determined shall conform to the requirement specified in Section 7.

PHYSICAL PROPERTIES AND TESTS

Tension Tests.

10. (*a*) The forgings shall conform to the minimum requirements as to tensile properties specified in Table I.

(*b*) The classification by size of the forging shall be determined by the specified diameter or thickness which governs the size of the prolongation from which the test specimen is taken.

(*c*) The elastic limit called for by these specifications shall be determined by an extensometer reading to 0.0002 in. The extensometer shall be attached to the specimen at the gage marks and not to the shoulders of the specimen nor to any part of the testing machine. When the specimen is in place and the extensometer attached, the testing machine shall be operated so as to increase the load on the specimen at a uniform rate. The observer shall watch the elongation of the specimen as shown by the extensometer and shall note, for this determination, the load at which the rate of elongation shows a sudden increase. The extensometer shall then be removed from the specimen, and the test continued to determine the tensile strength.

TABLE I.—TENSILE PROPERTIES

FOR FORGINGS WHOSE MAXIMUM OUTSIDE DIAMETER OR THICKNESS IS NOT OVER 10 IN. WHEN SOLID, AND NOT OVER 20 IN. WHEN BORED.

Size	Tensile Strength, lb. per sq. in.	Elastic Limit, lb. per sq. in.	Elongation in 2 in., per cent		Reduction of Area per cent	
			Inverse Ratio	Not under	Inverse Ratio	Not under
Up to 4 in. in outside diameter or thickness, 2-in. max. wall	90 000	55 000	$\frac{2\,100\,000}{\text{Tens. str.}}$	20.5	$\frac{4\,000\,000}{\text{Tens. str.}}$	39
Over 4 to 7 in. in outside diameter or thickness, $3\frac{1}{2}$-in. max. wall	85 000	50 000	$\frac{2\,000\,000}{\text{Tens. str.}}$	20.5	$\frac{3\,800\,000}{\text{Tens. str.}}$	39
Over 7 to 10 in. in outside diameter or thickness, 5-in. max. wall	85 000	50 000	$\frac{1\,900\,000}{\text{Tens. str.}}$	19.5	$\frac{3\,600\,000}{\text{Tens. str.}}$	37
Outside diameter or thickness not over 20 in., 5 to 8-in. wall	82 500	48 000	$\frac{1\,800\,000}{\text{Tens. str.}}$	19	$\frac{3\,400\,000}{\text{Tens. str.}}$	36

(*d*) Tests of forgings shall be made only after final treatment.

Bend Tests. 11. If specified by the purchaser, bend tests shall be made as follows:

(*a*) For the first and second classes by size, the test specimen shall stand being bent cold through 180 deg. around a pin 1 in. in diameter, without cracking on the outside of the bent portion.

(*b*) For the third and fourth classes by size, the test specimen shall stand being bent cold through 180 deg. around a pin $1\frac{1}{2}$ in. in diameter, without cracking on the outside of the bent portion.

Proof Tests. 12. Unless otherwise specified by the purchaser, all forgings shall be subjected to an impact proof test. The details of this test shall be agreed upon by the manufacturer and the purchaser.[1]

Test Specimens. 13. (*a*) Tension and bend test specimens shall be taken from a full-size prolongation of any forging. For forgings with large ends or collars the prolongation may be of the same cross-section as that

[1] For information relative to proof tests of finished forgings, see Appendix, pp. 191 and 192.

of the forging back of the large end or collar. Specimens may be taken from the forging itself with a hollow drill, if approved by the purchaser.

(*b*) The axis of the specimen shall be located at any point midway between the center and surface of solid forgings, and at any point midway between the inner and outer surfaces of the wall of bored forgings, and shall be parallel to the axis of the forging in the direction in which the metal is most drawn out.

(*c*) Tension test specimens shall conform to the dimensions shown in Fig. 1. The ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial.

(*d*) Bend test specimens shall be $\frac{1}{2}$ in. square in section with corners rounded to a radius not over $\frac{1}{16}$ in., and need not exceed 6 in. in length.

14. (*a*) One tension and, if specified by the purchaser, one bend test shall be made from each tempering charge. If more than one **Number of Tests.**

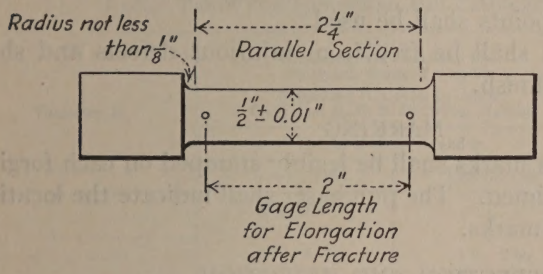
Radius not less than 1/8"
2 1/4"
Parallel Section
1/2 ± 0.01"
2"
Gage Length for Elongation after Fracture
Note:-The Gage Length, Parallel Section, and Fillets shall be as Shown, but the Ends may be of any Shape to fit the Holders of the Testing Machine in such a Way that the Load shall be axial.

FIG. 1.

quenching charge is represented in a tempering charge, one tension and, if specified, one bend test shall be made from each quenching charge. If more than one melt is represented in a quenching charge, one tension and, if specified, one bend test shall be made from each melt.

(*b*) If more than one class of forgings by size is represented in any lot, one tension and, if specified, one bend test from a forging of each class by size shall be made as specified in Sections 10, 11 and 13.

(*c*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*d*) If the percentage of elongation of any tension test specimen is less than that specified in Section 10 (*a*) and any part of the fracture is more than $\frac{3}{4}$ in. from the center of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

15. (*a*) If the results of the physical tests of any test lot do not **Retests.**

conform to the requirements specified, the manufacturer may retemper or requench and temper such lot, but not more than three additional times unless authorized by the purchaser, and retests shall be made as specified in Section 14.

(*b*) If the fracture of any tension test specimen shows over 15 per cent crystallin, a second test shall be made. If the fracture of the second specimen shows over 15 per cent crystallin, the forgings represented by such specimen shall be retempered or requenched and tempered. The fracture shall be considered crystallin if the crystals which it contains are so large that the cleavage planes or sides of these crystals are easily visible to the eye.

WORKMANSHIP AND FINISH

Workmanship. 16. The forgings shall conform to the sizes and shapes specified by the purchaser. Axles, shafts and similar forgings, unless otherwise specified, shall be rough-turned all over with an allowance of $\frac{1}{8}$ in. on the surface for finishing. In centering, 60-deg. centers with clearance drilled for points shall be used.

Finish. 17. The forgings shall be free from injurious defects and shall have a workmanlike finish.

MARKING

Marking. 18. Identification marks shall be legibly stamped on each forging and on each test specimen. The purchaser shall indicate the location of such identification marks.

INSPECTION AND REJECTION

Inspection. 19. (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the forgings ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the forgings are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

(*b*) The purchaser may make the tests to govern the acceptance or rejection of the forgings in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

Rejection. 20. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 19 (*b*) shall be reported within five working days from the receipt of samples.

(*b*) Forgings which show injurious defects while being finished by the purchaser will be rejected, and the manufacturer shall be notified.

21. Samples tested in accordance with Section 19 (*b*), which represent rejected forgings, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time. Rehearing.

APPENDIX.

As a guide in deciding on a proof test for quenched-and-tempered forgings, the following particulars regarding three established methods of testing are given.[1] These methods of proof testing are giving satisfactory results in practice.

PROOF TESTS FOR QUENCHED-AND-TEMPERED FORGINGS.

Diameter, in.	PENNSYLVANIA RAILROAD CO.; STANDARD STEEL WORKS CO. Supports 3 ft. Center to Center, Carried on M. C. B. Drop-Test Machine		NEW YORK CENTRAL LINES, Rigid Supports 5 ft. Center to Center CARNEGIE STEEL CO., Rigid Supports at Ends of Forgings
	Height of Drop, ft. and in.		
	1640-lb. Tup	2240-lb. Tup	Energy of Blow, ft.-lb.
4½	0 ft. 11 in.	.....	700
5	1 " 3 "	.....	900
5½	1 " 8 "	1 ft. 2 in.	1 200
6	2 " 2 "	1 " 7 "	1 700
6½	2 " 9 "	2 " 0 "	2 500
7	3 " 5 "	2 " 6 "	3 500
7½	4 " 3 "	3 " 1 "	4 700
8	5 " 1 "	3 " 8 "	6 000
8½	6 " 2 "	4 " 6 "	7 500
9	7 " 3 "	5 " 3 "	9 000
9½	8 " 7 "	6 " 3 "	10 000
10	10 " 0 "	7 " 4 "	11 000
10½	11 " 7 "	8 " 6 "	12 000
11	13 " 5 "	9 " 10 "	13 000
11½	15 " 3 "	11 " 1 "	14 000
12	17 " 4 "	12 " 8 "	15 000

The Pennsylvania System and the Standard Steel Works Co. require that all axles, shafts and similar forgings shall undergo an impact proof test on an A. R. A. drop-test machine, with supports

[1] For more detailed information concerning these methods of proof testing, see Report of Committee A-1 on Steel, Appendix IV, "Report on Proof Tests of Finished Forgings," *Proceedings*, Am. Soc. Testing Mats., Vol. XIV, Part I, p. 120 (1914); also, Report of Committee A-1 for 1917, *Proceedings*, Am. Soc. Testing Mats., Vol. XVII, Part I, pp. 115–117 (1917).

spaced 3 ft. center to center, two blows being struck with a tup weighing 1640 or 2240 lb. The forging is to have one of the points of support as near as practicable to one end for the first blow and as near as practicable to the other end for the second blow, the forging being turned 90 deg. on its longitudinal axis after the first blow. The requirements as to height of drop given in the accompanying table are derived from the following formulas:

$$\text{For the 1640-lb. tup: } H = 0.01\ D^3$$
$$\text{For the 2240-lb. tup: } H = 0.0073\ D^3$$

in which H is the height of drop in feet and D is the diameter of the forging at the center in inches.

The New York Central Lines and the Carnegie Steel Co. require that forgings shall be submitted to an impact proof test by having them carried on rigid supports and struck one blow at the center by a tup delivering the number of foot-pounds of energy shown in the accompanying table. The New York Central Lines space the supports 5 ft. center to center, while the Carnegie Steel Co. places the supports as near as practicable to the ends of the forgings.

STANDARD SPECIFICATIONS

FOR

QUENCHED-AND-TEMPERED ALLOY-STEEL AXLES, SHAFTS, AND OTHER FORGINGS FOR LOCOMOTIVES AND CARS[1]

Serial Designation: A 63 – 27

These specifications are issued under the fixed designation A 63; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ADOPTED, 1916; REVISED, 1918, 1921, 1927.

Scope.

1. (*a*) These specifications cover the various classes of alloy-steel forgings now commonly used in locomotive and car construction.

(*b*) The purposes for which these classes are frequently used are as follows:

Class K, for forgings for main and side rods, straps, piston rods, and all other forgings which are to be machined with milling cutters or complicated forming tools;

Class L, for forgings for driving and trailing-truck axles, crank pins, and other parts not requiring the use of milling cutters or complicated forming tools.

MANUFACTURE

Process.

2. The steel shall be made by either or both the following processes: open-hearth or electric-furnace.

Discard.

3. A sufficient discard shall be made from each ingot to secure freedom from injurious piping and undue segregation.

Prolongations for Tests.

4. Unless otherwise specified, for test purposes at least 20 per cent of the forgings shall be provided with prolongations or, at the manufacturer's option, a forging may be selected.

Boring

5. (*a*) Unless otherwise specified by the purchaser, all forgings over 7 in. in diameter shall be bored, and all axles, shafts and similar forgings shall be rough-turned all over. The boring shall be done before quenching.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

(*b*) If boring is specified, the diameter of the hole shall be at least 20 per cent of the maximum outside diameter or thickness of the forging, exclusive of collars and flanges.

Heat Treatment.

6. The procedure to be followed in quenching and tempering shall consist in allowing the objects, immediately after forging, to cool to a temperature below the critical range, under suitable conditions to prevent injury by too rapid cooling. They shall then be uniformly reheated to the proper temperature to refine the grain (a group thus reheated being known as a "quenching charge"), and quenched in some medium under substantially uniform conditions for each quenching charge. Finally, they shall be uniformly reheated to the proper temperature for tempering or "drawing back" (a group thus reheated being known as a "tempering charge"), and allowed to cool uniformly.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

7. (*a*) The steel shall conform to the following requirements as to chemical composition:

	Acid	Basic
Phosphorus, per cent	not over 0.05	not over 0.04
Sulfur, per cent	" " 0.05	" " 0.05

(*b*) The composition of alloy steel, other than phosphorus and sulfur, shall be agreed upon by the manufacturer and the purchaser.

Ladle Analyses.

8. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese and the elements specified in Section 7. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 7.

Check Analyses.

9. (*a*) An analysis may be made by the purchaser from a forging representing each melt. The chemical composition thus determined shall conform to the requirements specified in Section 7. Drillings for analysis may be taken from the forging or from a full-size prolongation of the same, at any point midway between the center and surface of solid forgings, and at any point midway between the inner and outer surfaces of the wall of bored forgings; or turnings may be taken from a test specimen.

(*b*) In addition to the complete analysis specified in Paragraph (*a*), a phosphorus determination may be made by the purchaser from each broken tension test specimen. The phosphorus content thus determined shall conform to the requirement specified in Section 7.

PHYSICAL PROPERTIES AND TESTS

10. (*a*) The forgings shall conform to the requirements as to tensile properties specified in Table I. **Tension Tests.**

(*b*) The classification by size of the forging shall be determined by the specified diameter or thickness which governs the size of the prolongation from which the test specimen is taken.

(*c*) The elastic limit called for by these specifications shall be determined by an extensometer reading to 0.0002 in. The extensometer shall be attached to the specimen at the gage marks and not to the

TABLE I.—TENSILE PROPERTIES.

FOR FORGINGS WHOSE MAXIMUM OUTSIDE DIAMETER OR THICKNESS IS NOT OVER 10 IN. WHEN SOLID, AND NOT OVER 20 IN. WHEN BORED.

Class	Size	Tensile Strength, lb. per sq. in.	Elastic Limit, min., lb. per sq. in.	Elongation in 2 in., min., per cent	Reduction of Area, min, per cent
K ALLOY STEEL, QUENCHED AND TEMPERED	Up to 2 in. in outside diameter or thickness, 1-in. max. wall	95 000 – 115 000	70 000	20	50
	Over 2 to 4 n. in outside diameter or thickness, 2-in. max. wall	90 000 – 110 000	65 000	20	50
	Over 4 to 7 in. in outside diameter or thickness, 3½-in. max. wall	90 000 – 110 000	65 000	20	50
	Over 7 to 10 in. in outside diameter or thickness, 5-in. max. wall	90 000 – 110 000	65 000	20	50
	Outside diameter or thickness not over 20 in., 5 to 8-in. wall	85 000 – 105 000	60 000	20	50
L ALLOY STEEL, QUENCHED AND TEMPERED	Up to 2 in. in outside diameter or thickness, 1-in. max. wall	105 000 – 125 000	80 000	20	50
	Over 2 to 4 in. in outside diameter or thickness, 2-in. max. wall	100 000 – 120 000	75 000	20	50
	Over 4 to 7 in. in outside diameter or thickness, 3½-in. max. wall	100 000 – 120 000	75 000	20	50
	Over 7 to 10 in. in outside diameter or thickness, 5-in. max. wall	100 000 – 120 000	75 000	18	45
	Outside diameter or thickness not over 20 in., 5 to 8-in. wall	95 000 – 115 000	70 000	18	45

shoulders of the specimen nor to any part of the testing machine. When the specimen is in place and the extensometer attached, the testing machine shall be operated so as to increase the load on the specimen at a uniform rate. The observer shall watch the elongation of the specimen as shown by the extensometer and shall note, for this determination, the load at which the rate of elongation shows a sudden increase. The extensometer shall then be removed from the specimen, and the test continued to determine the tensile strength.

(*d*) Tests of forgings shall be made only after final treatment.

11. If specified by the purchaser, bend tests shall be made as follows: **Bend Tests.**

(*a*) For the first, second and third classes by size, the test specimen shall stand being bent cold through 180 deg. around a pin 1 in. in diameter, without cracking on the outside of the bent portion.

(*b*) For the fourth and fifth classes by size, the test specimen shall stand being bent cold through 180 deg. around a pin $1\frac{1}{2}$ in. in diameter, without cracking on the outside of the bent portion.

Proof Tests.

12. Unless otherwise specified by the purchaser, all forgings shall be subjected to an impact proof test. The details of this test shall be agreed upon by the manufacturer and the purchaser.[1]

Test Specimens.

13. (*a*) Tension and bend test specimens shall be taken from a full-size prolongation of any forging. For forgings with large ends or collars the prolongation may be of the same cross-section as that of the forging back of the large end or collar. Specimens may be taken from the forging itself with a hollow drill, if approved by the purchaser.

(*b*) The axis of the specimen shall be located at any point midway between the center and surface of solid forgings, and at any point

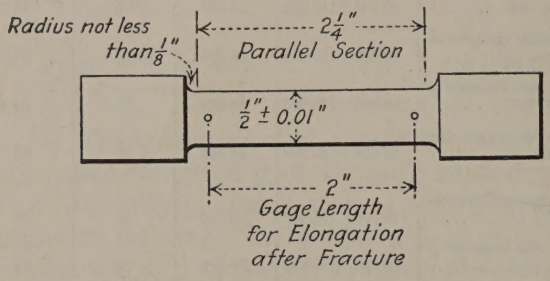

Radius not less than 1/8"
2 1/4"
Parallel Section
1/2" ± 0.01"
2"
Gage Length for Elongation after Fracture
Note:-The Gage Length, Parallel Section, and Fillets shall be as Shown, but the Ends may be of any Shape to fit the Holders of the Testing Machine in such a Way that the Load shall be axial.

FIG. 1.

midway between the inner and outer surfaces of the wall of bored forgings, and shall be parallel to the axis of the forging in the direction in which the metal is most drawn out.

(*c*) Tension test specimens shall conform to the dimensions shown in Fig. 1. The ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial.

(*d*) Bend test specimens shall be $\frac{1}{2}$ in. square in section with corners rounded to a radius not over $\frac{1}{16}$ in., and need not exceed 6 in. in length.

Number of Tests.

14. (*a*) One tension and, if specified by the purchaser, one bend test shall be made from each tempering charge. If more than one quenching charge is represented in a tempering charge, one tension and, if specified, one bend test shall be made from each quenching

[1] For information relative to proof tests of finished forgings, see Appendix, pp. 198 and 199.

charge. If more than one melt is represented in a quenching charge, one tension and, if specified, one bend test shall be made from each melt.

(*b*) If more than one class of forgings by size is represented in any lot, one tension and, if specified, one bend test from a forging of each class by size shall be made as specified in Sections 10, 11 and 13.

(*c*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*d*) If the percentage of elongation of any tension test specimen is less than that specified in Section 10 (*a*) and any part of the fracture is more than $\frac{3}{4}$ in. from the center of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

Retests.

15. (*a*) If the results of the physical tests of any test lot do not conform to the requirements specified, the manufacturer may retemper or requench and temper such lot, but not more than three additional times unless authorized by the purchaser, and retests shall be made as specified in Section 14.

(*b*) If the fracture of any tension test specimen shows over 15 per cent crystallin, a second test shall be made. If the fracture of the second specimen shows over 15 per cent crystallin, the forgings represented by such specimen shall be retempered or requenched and tempered. The fracture shall be considered crystallin if the crystals which it contains are so large that the cleavage planes or sides of these crystals are easily visible to the eye.

WORKMANSHIP AND FINISH

Workmanship.

16. The forgings shall conform to the sizes and shapes specified by the purchaser. Axles, shafts and similar forgings, unless otherwise specified, shall be rough-turned all over with an allowance of $\frac{1}{8}$ in. on the surface for finishing. In centering, 60-deg. centers with clearance drilled for points shall be used.

Finish.

17. The forgings shall be free from injurious defects and shall have a workmanlike finish.

MARKING

Marking.

18. Identification marks shall be legibly stamped on each forging and on each test specimen. The purchaser shall indicate the location of such identification marks.

INSPECTION AND REJECTION

Inspection.

19. (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being

performed, to all parts of the manufacturer's works which concern the manufacture of the forgings ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the forgings are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

(*b*) The purchaser may make the tests to govern the acceptance or rejection of the forgings in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

Rejection. 20. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 19 (*b*) shall be reported within five working days from the receipt of samples.

(*b*) Forgings which show injurious defects while being finished by the purchaser will be rejected, and the manufacturer shall be notified.

Rehearing. 21. Samples tested in accordance with Section 19 (*b*), which represent rejected forgings, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

APPENDIX

As a guide in deciding on a proof test for quenched-and-tempered forgings, the following particulars regarding three established methods of testing are given.[1] These methods of proof testing are giving satisfactory results in practice.

The Pennsylvania System and the Standard Steel Works Co. require that all axles, shafts and similar forgings shall undergo an impact proof test on an A. R. A. drop-test machine, with supports spaced 3 ft. center to center, two blows being struck with a tup weighing 1640 or 2240 lb. The forging is to have one of the points of support as near as practicable to one end for the first blow and as near as practicable to the other end for the second blow, the forging being turned 90 deg. on its longitudinal axis after the first blow. The requirements as to height of drop given in the accompanying table are derived from the following formulas:

[1] For more detailed information concerning these methods of proof testing, see Report of Committee A-1 on Steel, Appendix IV, "Report on Proof Tests of Finished Forgings," *Proceedings*, Am. Soc. Testing Mats., Vol. XIV, Part I, p. 120 (1914); also, Report of Committee A-1 for 1917, *Proceedings*, Am. Soc. Testing Mats., Vol. XVII, Part I, pp. 115–117 (1917).

For the 1640-lb. tup: $H = 0.01\ D^3$
For the 2240-lb. tup: $H = 0.0073\ D^3$

in which H is the height of drop in feet and D is the diameter of the forging at the center in inches.

The New York Central Lines and the Carnegie Steel Co. require that forgings shall be submitted to an impact proof test by having

PROOF TESTS FOR QUENCHED-AND-TEMPERED FORGINGS.

Diameter, in.	PENNSYLVANIA RAILROAD CO.; STANDARD STEEL WORKS CO. Supports 3 ft. Center to Center, Carried on M. C. B. Drop-Test Machine		NEW YORK CENTRAL LINES, Rigid Supports 5 ft. Center to Center CARNEGIE STEEL CO., Rigid Supports at Ends of Forgings
	Height of Drop, ft. and in.		
	1640-lb. Tup	2240-lb. Tup	Energy of Blow, ft.-lb.
4½	0 ft. 11 in.	.....	700
5	1 " 3 "	.....	900
5½	1 " 8 "	1 ft. 2 in.	1 200
6	2 " 2 "	1 " 7 "	1 700
6½	2 " 9 "	2 " 0 "	2 500
7	3 " 5 "	2 " 6 "	3 500
7½	4 " 3 "	3 " 1 "	4 700
8	5 " 1 "	3 " 8 "	6 000
8½	6 " 2 "	4 " 6 "	7 500
9	7 " 3 "	5 " 3 "	9 000
9½	8 " 7 "	6 " 3 "	10 000
10	10 " 0 "	7 " 4 "	11 000
10½	11 " 7 "	8 " 6 "	12 000
11	13 " 5 "	9 " 10 "	13 000
11½	15 " 3 "	11 " 1 "	14 000
12	17 " 4 "	12 " 8 "	15 000

them carried on rigid supports and struck one blow at the center by a tup delivering the number of foot-pounds of energy shown in the accompanying table. The New York Central Lines space the supports 5 ft. center to center, while the Carnegie Steel Co. places the supports as near as practicable to the ends of the forgings.

STANDARD SPECIFICATIONS
FOR
CARBON-STEEL FORGINGS FOR LOCOMOTIVES[1]

Serial Designation: A 20 – 27

These specifications are issued under the fixed designation A 20; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ADOPTED, 1912; REVISED, 1913, 1914, 1916, 1921, 1927.

Scope.

1. These specifications cover untreated and annealed carbon-steel driving axles, engine and trailing-truck axles, main and side rods, straps, crank pins, piston rods, and annealed car and tender axles.

Basis of Purchase.

2. The manufacturer may, at his option, furnish annealed forgings when untreated forgings are specified by the purchaser, provided they conform to the requirements specified for untreated forgings.

MANUFACTURE

Process.

3. The steel shall be made by either or both the following processes: open-hearth or electric-furnace.

Discard.

4. A sufficient discard shall be made from each ingot to secure freedom from injurious piping and undue segregation.

Prolongations for Tests.

5. Unless otherwise specified, for test purposes at least 20 per cent of the forgings shall be provided with prolongations or, at the manufacturer's option, a forging may be selected.

Heat Treatment.

6. The procedure to be followed in annealing shall consist in allowing the objects, immediately after forging, to cool to a temperature below the critical range, under suitable conditions to prevent injury by too rapid cooling. They shall then be uniformly reheated to the proper temperature to refine the grain (a group thus reheated being known as an "annealing charge"), and allowed to cool uniformly.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

7. The steel shall conform to the following requirements as to chemical composition:

Manganese	0.40 – 0.70 per cent
Phosphorus	not over 0.05 "
Sulfur	" " 0.05 "

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

8. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon and the elements specified in Section 7. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 7. **Ladle Analyses.**

9. An analysis may be made by the purchaser from a forging representing each melt. The chemical composition thus determined shall conform to the requirements specified in Section 7. Drillings for analysis may be taken from the forging or from a full-size prolongation of the same, at any point midway between the center and surface; or turnings may be taken from a test specimen. **Check Analyses.**

TABLE I.—TENSILE PROPERTIES.

FOR FORGINGS WHOSE MAXIMUM OUTSIDE DIAMETER OR OVER-ALL THICKNESS IS NOT OVER 12 IN. WHEN UNTREATED AND NOT OVER 20 IN. WHEN ANNEALED.

Size. Outside Diameter or Over-all Thickness	Tensile Strength, lb. per sq. in.	Yield Point, lb. per sq. in.	Elongation in 2 in., per cent		Reduction of Area, per cent	
			Inverse Ratio	Not under	Inverse Ratio	Not under
UNTREATED.						
Not over 8 in.	75 000	0.5 tens. str.	$\frac{1\,600\,000}{\text{Tens. str.}}$	18	$\frac{2\,200\,000}{\text{Tens. str.}}$	24
Over 8 to 12 in., inclusive	75 000	0.5 tens. str.	$\frac{1\,500\,000}{\text{Tens. str.}}$	17	$\frac{2\,000\,000}{\text{Tens. str.}}$	23
ANNEALED.						
Not over 8 in.	80 000	0.5 tens. str.	$\frac{1\,800\,000}{\text{Tens. str.}}$	20	$\frac{2\,800\,000}{\text{Tens. str.}}$	32
Over 8 to 12 in., inclusive	80 000	0.5 tens. str.	$\frac{1\,725\,000}{\text{Tens. str.}}$	19	$\frac{2\,640\,000}{\text{Tens. str.}}$	30
Over 12 to 20 in., inclusive	80 000	0.5 tens. str.	$\frac{1\,650\,000}{\text{Tens. str.}}$	18	$\frac{2\,400\,000}{\text{Tens. str.}}$	28

PHYSICAL PROPERTIES AND TESTS

10. (*a*) The forgings shall conform to the minimum requirements as to tensile properties specified in Table I. **Tension Tests.**

(*b*) The classification by size of the forging shall be determined by the specified diameter or thickness which governs the size of the prolongation from which the test specimen is taken.

(*c*) The yield point shall be determined by the drop of the beam of the testing machine.

(*d*) Tests of forgings shall be made only after final treatment.

11. (*a*) Tension test specimens shall be taken from a full-size prolongation of any forging. For forgings with large ends or collars **Tension Test Specimens.**

the prolongation may be of the same cross-section as that of the forging back of the large end or collar. Specimens may be taken from the forging itself with a hollow drill, if approved by the purchaser.

(*b*) The axis of the specimen shall be located at any point midway between the center and surface of the forging, and shall be parallel to the axis of the forging in the direction in which the metal is most drawn out.

(*c*) The specimens shall conform to the dimensions shown in Fig. 1. The ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial.

Number of Tests.

12. Unless otherwise specified by the purchaser, tests shall be made as follows:

(*a*) For untreated forgings, one tension test shall be made from each melt.

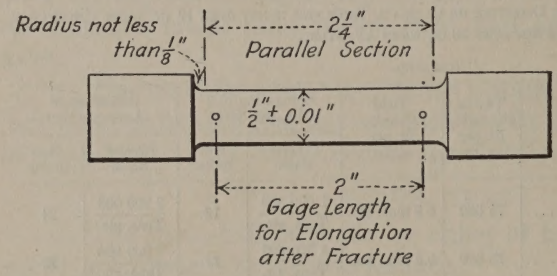

Radius not less than 1/8"
2 1/4"
Parallel Section
1/2" ± 0.01"
2"
Gage Length for Elongation after Fracture
Note:-The Gage Length, Parallel Section, and Fillets shall be as Shown, but the Ends may be of any Shape to fit the Holders of the Testing Machine in such a Way that the Load shall be axial.

FIG. 1.

(*b*) For annealed forgings, one tension test shall be made from each annealing charge. If more than one melt is represented in an annealing charge, one tension test shall be made from each melt.

(*c*) If more than one class of forgings by size is represented in any lot, one tension test from a forging of each class by size shall be made as specified in Sections 10 and 11.

(*d*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*e*) If the percentage of elongation of any test specimen is less than that specified in Section 10 (*a*) and any part of the fracture is more than $\frac{3}{4}$ in. from the center of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

Retests.

13. (*a*) If the results of the physical tests of any test lot do not conform to the requirements specified, the manufacturer may re-anneal such lot, but not more than three additional times unless authorized by the purchaser, and retests shall be made as specified in Section 12.

(*b*) When annealed forgings are specified, if the fracture of any test specimen shows over 15 per cent crystallin, a second test shall be made. If the fracture of the second specimen shows over 15 per cent crystallin, the forgings represented by such specimen shall be re-annealed. The fracture shall be considered crystallin if the crystals which it contains are so large that the cleavage planes or sides of these crystals are easily visible to the eye.

WORKMANSHIP AND FINISH

Workmanship.

14. The forgings shall conform to the sizes and shapes specified by the purchaser. When centered, 60-deg. centers with clearance drilled for points shall be used.

Finish.

15. The forgings shall be free from injurious defects and shall have a workmanlike finish.

MARKING

Marking.

16. Identification marks shall be legibly stamped on each forging and on each test specimen. The purchaser shall indicate the location of such identification marks.

INSPECTION AND REJECTION

Inspection.

17. (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the forgings ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the forgings are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

(*b*) The purchaser may make the tests to govern the acceptance or rejection of the forgings in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

Rejection.

18. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 17 (*b*) shall be reported within five working days from the receipt of samples.

(*b*) Forgings which show injurious defects while being finished by the purchaser will be rejected, and the manufacturer shall be notified.

Rehearing.

19. Samples tested in accordance with Section 17 (*b*), which represent rejected forgings, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

STANDARD SPECIFICATIONS
FOR
CARBON-STEEL CAR AND TENDER AXLES[1]

Serial Designation: A 21 – 27

These specifications are issued under the fixed designation A 21; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ADOPTED, 1901; REVISED, 1905, 1913, 1914, 1918, 1927.

Scope.

1. These specifications cover tapered axles up to and including those $6\frac{1}{2}$ in. in nominal diameter at the center. Axles over $6\frac{1}{2}$ in. in diameter at the center shall be annealed and shall be in accordance with the Standard Specifications for Carbon-Steel Forgings for Locomotives (Serial Designation: A 20) of the American Society for Testing Materials.[2]

MANUFACTURE

Process.

2. The steel shall be made by the open-hearth or electric-furnace process.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

3. The steel shall conform to the following requirements as to chemical composition:

Carbon	0.40 – 0.55	per cent
Manganese	0.40 – 0.70	"
Phosphorus, not over	0.05	"
Sulfur, not over	0.06	"

Ladle Analyses.

4. An analysis shall be made by the manufacturer from a test ingot taken during the pouring of each melt, to determine the percentage of carbon, manganese, phosphorus, sulfur and, when specified, silicon. Drillings for analysis shall be taken not less than $\frac{1}{4}$ in. beneath the surface of the test ingot. A copy of this analysis shall be given to the purchaser or his representative. This analysis shall conform to the requirements specified in Section 3.

Check Analyses.

5. Analyses may be made by the purchaser from one axle representing each melt. The chemical composition thus determined shall conform to the requirements specified in Section 3. The drillings for these analyses shall be from one end of the test axle at any point midway between the center and surface, using a $\frac{5}{8}$-in. drill.

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

[2] See p. 200

PHYSICAL PROPERTIES AND TESTS

6. (*a*) The test axle shall be so placed on supports 3 ft. apart, that the tup will strike it midway between the ends. It shall stand without fracture five blows from a tup of 2240 lb. falling from a height H, such that H in feet equals the square of the diameter of the axle at the center in inches, $H = d^2$. The axle shall be turned through 180 deg. after the first and third blows. Drop Tests.

(*b*) Before an axle is drop tested, the center shall be calipered to the nearest $\frac{1}{8}$ in., and the height of drop in feet, to the nearest $\frac{1}{2}$ ft., shall not be less than the square of the actual diameter, at the center, in inches.

(*c*) The permanent set produced by the first blow shall not exceed that given by the following formulas, in which L = length of axle in inches, and d = diameter of axle at center in inches.

For axles over 65 in. in length:

$$\left(\frac{L}{1.9d} - \frac{d}{2}\right) + \tfrac{1}{2} \text{ in} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

For axles 65 in. or under in length:

$$\left(\frac{L}{1.9d} - \frac{d}{2}\right) + 1 \text{ in} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

(*d*) The American Railway Association has adopted five standard sizes of axles, the requirements for which, based on the above formulas, are given in the following table:

TABLE I.

Classification of Axles	Size of Journal, in.	Diameter of Axle at Center, in.	Length of Axle, in.	Height of Drop, ft.	Number of Blows	Maximum Permanent Set, in.
A	$3\frac{3}{4}$ by 7	$4\frac{1}{4}$ $4\frac{3}{8}$ $4\frac{1}{2}$	$83\frac{1}{4}$	18 19 20	5	$8\frac{3}{4}$ $8\frac{3}{8}$ 8
B	$4\frac{1}{4}$ by 8	$4\frac{3}{4}$ $4\frac{7}{8}$ 5	$84\frac{1}{4}$	$22\frac{1}{2}$ $23\frac{1}{2}$ 25	5	$7\frac{1}{2}$ $7\frac{1}{4}$ 7
C	5 by 9	$5\frac{3}{8}$ $5\frac{1}{2}$ $5\frac{5}{8}$	$86\frac{1}{2}$	29 30 $31\frac{1}{2}$	5	$6\frac{1}{4}$ 6 $5\frac{3}{4}$
D	$5\frac{1}{2}$ by 10	$5\frac{7}{8}$ 6 $6\frac{1}{8}$	$88\frac{1}{2}$	$34\frac{1}{2}$ 36 $37\frac{1}{2}$	5	$5\frac{1}{2}$ $5\frac{1}{4}$ 5
E	6 by 11	$6\frac{7}{16}$ $6\frac{9}{16}$ $6\frac{11}{16}$	$90\frac{3}{4}$	$41\frac{1}{2}$ 43 $44\frac{1}{2}$	5	$4\frac{3}{4}$ $4\frac{1}{2}$ $4\frac{1}{4}$

(*e*) The maximum permanent set is the difference between the distance from a straight edge to the middle point of the axle, measured before the first blow, and the distance measured in the same manner after the blow. The straight edge shall rest only on the end collars or the ends of the axle.

(*f*) The temperature of the test axle shall be between 40 and 120° F. (4 and 50° C.).

Drop Test Machine.

7. The anvil of the drop-test machine shall be supported on 12 springs, as shown on the A.R.A. drawings, and shall be free to move in a vertical direction, and shall weigh 17,500 lb. The radii of the striking face of the tup and of the supports shall be 5 in.

Number of Tests.

8. One drop test shall be made from each melt. Not less than 15 tons shall be offered from any one melt unless otherwise specified.

WORKMANSHIP AND FINISH

Workmanship.

9. (*a*) All axles shall be made and finished in a workmanlike manner and shall conform to the sizes and shaped specified by the customer and all journals and wheel seats shall be rough turned. In centering, unless otherwise specified, 60-deg. centers shall be used, with large diameter of counter-sink not less than $\frac{7}{8}$ in. and with clearance drilled $\frac{1}{2}$ in. deep.

(*b*) Unless otherwise specified, axles shall be smooth forged, except the wheel seats and journals, which shall be rough turned.

Finish.

10. The axles shall be free from injurious defects and shall have a workmanlike finish.

PERMISSIBLE VARIATIONS AND WEIGHTS

Permissible Variations.

11. (*a*) The length of the axles shall not be less than that specified and not more than $\frac{1}{8}$ in. over.

(*b*) *Smooth Forged Axles.*—The diameters of the straight center portion of the axles and the black collars shall not be less than that specified, and shall not be more than $\frac{1}{4}$ in. over. The intermediate portion of the axles shall not be under the dimensions specified, and shall be forged to a straight taper in a workmanlike manner.

(*c*) *Rough Turned Axles.*—The diameters of the straight center portion and the black collars shall not be less than that specified. The straight center portion shall not be more than $\frac{1}{8}$ in. over, and the black collars not more than $\frac{1}{4}$ in. over the diameter specified. The intermediate portion of the axles shall not be under the dimensions specified, and shall be turned to a straight taper in a workmanlike manner.

(*d*) The rough-turned diameter of the journals and wheel seats shall be from $\frac{1}{8}$ to $\frac{1}{4}$ in. over the finished sizes to provide for proper finishing.

12. (*a*) The maximum weights of smooth-forged and rough-turned axles given in Section 6 (*d*) in any shipment shall not exceed those given in Table II. **Weights.**

TABLE II.

Classification of Axles	Size of Journal, in.	Maximum Weight, lb.	
		Smooth Forged with Rough Turned Journals and Wheel Seats	Rough Turned All Over
A	$3\frac{3}{4}$ by 7	435	425
B	$4\frac{1}{4}$ by 8	530	520
C	5 by 9	705	695
D	$5\frac{1}{2}$ by 10	835	825
E	6 by 11	1015	1005

(*b*) Axles shown in Table II shall be billed at actual weight, except that all weight in excess of the above maximum figures shall be at the expense of the manufacturer.

MARKING

13. Each axle shall have the manufacturer's name or brand legibly stamped on one of the black collars, and the melt number, the month and year when made stamped on the other, unless otherwise specified. **Marking.**

INSPECTION AND REJECTION

14. (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the axles ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the axles are being furnished in accordance with these specifications. Tests and inspection at the place of manufacture shall be made prior to shipment. **Inspection.**

(*b*) The purchaser may make the chemical tests to govern the acceptance or rejection of the axles in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

(*c*) All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection.

15. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 14 (*b*) shall be reported within five working days from the receipt of samples.

(*b*) Axles which show injurious defects while being finished by the purchaser will be rejected, and the manufacturer shall be notified.

Rehearing.

16. Samples tested in accordance with Section 14 (*b*), which represent rejected axles, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

STANDARD SPECIFICATIONS
FOR
COLD-ROLLED STEEL AXLES[1]

Serial Designation: A 22 – 21

These specifications are issued under the fixed designation A 22; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ADOPTED, 1913; REVISED, 1914, 1916, 1921.

MANUFACTURE

Process.

1. (*a*) The steel shall be made by either or both the following processes: open-hearth or electric-furnace.

(*b*) The axles shall be cold-rolled to finished size from hot-rolled bars.

Discard.

2. A sufficient discard shall be made from each ingot to secure freedom from injurious piping and undue segregation.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

3. The steel shall conform to the following requirements as to chemical composition:

Carbon	not over 0.40 per cent
Manganese	0.40 – 0.80 "
Phosphorus	not over 0.05 "
Sulfur	" " 0.05 "

Ladle Analyses.

4. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements specified in Section 3. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 3.

Check Analyses.

5. An analysis may be made by the purchaser from an axle representing each melt. The chemical composition thus determined shall conform to the requirements specified in Section 3. Drillings for analysis may be taken from the axle or from a full-size prolongation of the same, at any point midway between the center and surface; or turnings may be taken from a test specimen.

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

PHYSICAL PROPERTIES AND TESTS

Tension Tests.

6. (*a*) The axles shall conform to the following minimum requirements as to tensile properties:

Tensile strength, lb. per sq. in.	70 000
Elastic limit, " "	60 000
Elongation in 2 in., per cent	18
Reduction of area, "	35

(*b*) The elastic limit called for by these specifications shall be determined by an extensometer reading to 0.0002 in. The extensometer shall be attached to the specimen at the gage marks and not to the shoulders of the specimen nor to any part of the testing machine. When the specimen is in place and the extensometer attached, the testing machine shall be operated so as to increase the load on the specimen at a uniform rate.

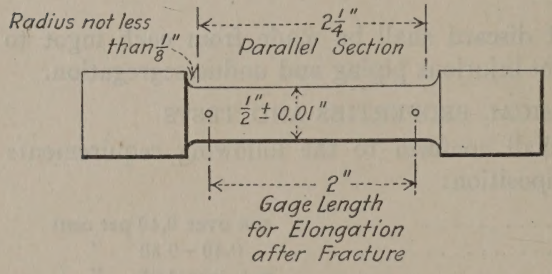

Radius not less than 1/8"
2 1/4"
Parallel Section
1/2" ± 0.01"
2"
Gage Length for Elongation after Fracture
Note:-The Gage Length, Parallel Section, and Fillets shall be as Shown, but the Ends may be of any Shape to fit the Holders of the Testing Machine in such a Way that the Load shall be axial.

FIG. 1.

The observer shall watch the elongation of the specimen as shown by the extensometer and shall note, for this determination, the load at which the rate of elongation shows a sudden increase. The extensometer shall then be removed from the specimen, and the test continued to determine the tensile strength.

Bend Tests.

7. The test specimen shall bend cold through 180 deg. around a pin 1 in. in diameter, without cracking on the outside of the bent portion.

Test Specimens.

8. (*a*) Tension and bend test specimens shall be taken from the full-size prolongation of the axle. The axis of the specimen shall be located at any point midway between the center and surface and shall be parallel to the axis of the axle.

(*b*) Tension test specimens shall conform to the dimensions shown in Fig. 1. The ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial.

(*c*) Bend test specimens shall be $\frac{1}{2}$ in. square in section with corners rounded to a radius not over $\frac{1}{16}$ in., and need not exceed 6 in. in length.

Number of Tests.

9. (*a*) One tension and one bend test shall be made from each lot of 50 axles or less from each melt.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 6(*a*) and any part of the fracture is more than $\frac{3}{4}$ in. from the center of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

WORKMANSHIP AND FINISH

Workmanship.

10. The axles shall conform to the sizes and shapes specified by the purchaser, and shall not vary more than 0.002 in. from the diameter specified. When centered, 60-deg. centers with clearance drilled for points shall be used.

Finish.

11. The axles, either finished or plain, shall be straight and free from injurious defects, and shall have a workmanlike finish.

MARKING

Marking.

12. Identification marks shall be legibly stamped on each axle, and on each test specimen. The purchaser shall indicate the location of such identification marks.

INSPECTION AND REJECTION

Inspection.

13. (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the axles ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the axles are being furnished in accordance with these specifications. Tests and inspection at the place of manufacture shall be made prior to shipment.

(*b*) The purchaser may make the tests to govern the acceptance or rejection of the axles in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

(*c*) All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection.

14. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 13 (*b*) shall be reported within five working days from the receipt of samples.

(*b*) Axles which show injurious defects while being finished by the purchaser will be rejected, and the manufacturer shall be notified.

Rehearing.

15. Samples tested in accordance with Section 13 (*b*), which represent rejected axles, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

STANDARD SPECIFICATIONS
FOR
WROUGHT SOLID CARBON-STEEL WHEELS FOR ELECTRIC RAILWAY SERVICE[1]

Serial Designation: A 25 - 24

These specifications are issued under the fixed designation A 25; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ADOPTED, 1913; REVISED 1916, 1924

MANUFACTURE

1. The steel shall be made by the open-hearth process. **Process.**

2. A sufficient discard shall be made from each ingot to secure freedom from injurious piping and undue segregation. **Discard.**

CHEMICAL PROPERTIES AND TESTS

3. The steel shall conform to the following requirements as to chemical composition: **Chemical Composition.**

	Acid	Basic
Carbon, per cent	0.60 – 0.80	0.65 – 0.85
Manganese, "	0.55 – 0.80	0.55 – 0.80
Phosphorus, "	not over 0.05	not over 0.05
Sulfur, "	" " 0.05	" " 0.05
Silicon, "	0.15 – 0.35	0.10 – 0.30

4. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements specified in Section 3. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined, together with such identifying records as may be desired, shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 3. **Ladle Analysis.**

5. An analysis may be made by the purchaser from a wheel representing each melt. The chemical composition thus determined shall conform to the requirements specified in Section 3. A sample may be taken from any one point in the plate; or two samples may be taken, in which case they shall be on radii at right angles to each other. Samples shall not be taken in such a way as to impair the **Check Analysis.**

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

usefulness of the wheel. Drillings for analysis shall be taken by boring entirely through the sample parallel to the axis of the wheel; they shall be clean and free from scale, oil and other foreign substances. All drillings from any one wheel shall be thoroughly mixed together.

MATING

Mating.

6. The wheels shall be mated as to tape sizes and shipped in pairs.

PERMISSIBLE VARIATIONS IN DIMENSIONS[1]

Permissible Variations.

7. The wheels shall conform to the dimensions specified within the following permissible variations:

FLANGE

(*a*) *Height of Flange.*—The height of flange shall not vary more than $\frac{1}{16}$ in. from that specified.

(*b*) *Thickness of Flange.*—The thickness of flange shall not vary more than $\frac{1}{16}$ in. from that specified.

(*c*) *Radius of Throat.*—The radius of throat shall not vary more than $\frac{1}{16}$ in. from that specified.

RIM

(*d*) *Thickness of Rim.*—The thickness of rim shall not vary more than $\frac{1}{4}$ in. over nor more than $\frac{1}{8}$ in. under that specified. The thickness of rim shall be measured radially of the wheel on the front face and is the distance from the inner edge of the rim to the point at which a base line, drawn parallel to the axis of the wheel from the point of tangency of the throat and tread, meets the front face.

(*e*) *Width of Rim.*—The width of rim shall not vary more than $\frac{1}{8}$ in. from that specified.

(*f*) *Plane.*—The wheels shall be gaged with a ring gage placed concentric with and perpendicular to the axis of the wheel. For all points on the back of the rim equi-distant from the center, the variation from the plane of the gage when so placed shall not exceed $\frac{1}{16}$ in.

(*g*) *Rotundity.*—The tread shall be gaged with a ring gage, and the opening between the tread and this gage at any point shall not exceed $\frac{1}{16}$ in.

(*h*) *Block Marks on Tread.*—Block marks shall not exceed $\frac{1}{64}$ in. in height.

(*i*) *Tape Sizes.*—Wheels with treads under 3 in. in width shall not vary more than 6 tapes over nor more than 4 tapes under the size specified. Wheels with treads 3 in. or over in width shall not

[1] To facilitate the use of these specifications, the various dimensions are illustrated in Fig. 1, and the permissible variations in those dimensions are also given in tabular form in Table I.

vary more than 9 tapes over nor more than 5 tapes under the size specified.

(*j*) *Limit-of-Wear Groove.*—When a limit-of-wear groove is specified, its location shall not vary more than $\frac{1}{16}$ in. from that specified.

TABLE I.—PERMISSIBLE VARIATIONS IN DIMENSIONS OF WROUGHT STEEL WHEELS FOR ELECTRIC RAILWAY SERVICE.

Dimensions	Permissible Variations in Dimensions	
	Over	Under
FLANGE		
(*a*) Height	$\frac{1}{16}$ in.	$\frac{1}{16}$ in.
(*b*) Thickness	$\frac{1}{16}$ in.	$\frac{1}{16}$ in.
(*c*) Radius of Throat	$\frac{1}{16}$ in.	$\frac{1}{16}$ in.
RIM		
(*d*) Thickness, from Inner Edge to Intersection of Throat and Tread	$\frac{1}{4}$ in.	$\frac{1}{8}$ in.
(*e*) Width	$\frac{1}{8}$ in.	$\frac{1}{8}$ in
(*f*) Maximum Departure of any Circle on Back Face from Plane	$\frac{1}{16}$ in.	
(*g*) Maximum Departure of Tread from Rotundity	$\frac{1}{16}$ in.	
(*h*) Maximum Height of Block Marks on Tread	$\frac{1}{64}$ in.	
(*i*) Tape Sizes:		
1. For Treads under 3 in. in Width	6	4
2. For Treads 3 in. or over in Width	9	5
(*j*) Limit-of-Wear Groove: Maximum Departure from Specified Position	$\frac{1}{16}$ in.	
PLATE		
(*k*) Thickness, Variation for each $\frac{1}{8}$ in. in Thickness	....	$\frac{1}{32}$ in.
HUB		
(*l*) 1. Diameter	$\frac{3}{4}$ in.	0
2. Minimum Thickness of Wall, for Bore 6 in. or under	1 in.	
3. Minimum Thickness of Wall, for Bore over 6 in	$1\frac{1}{4}$ in.	
4. Maximum Variation in Thickness of Wall in any One Wheel	$\frac{3}{8}$ in.	
(*m*) Length	$\frac{1}{8}$ in.	$\frac{1}{8}$ in.
(*n*) Projection beyond Back Face of Rim	$\frac{1}{16}$ in.	$\frac{1}{16}$ in.
BORE		
(If not specified, Rough Bore shall be $\frac{1}{4}$ in. less than Finished Bore.)		
(*o*) Diameter of Rough Bore	$\frac{1}{16}$ in.	$\frac{1}{8}$ in.
(*p*) Maximum Depth of Black Spots in Rough Bore within 2 in. of End of Bore	$\frac{1}{16}$ in.	
(*q*) Maximum Eccentricity of Rough Bore in Relation to Tread	$\frac{3}{64}$ in.	

NOTE.—The letter used for each dimension in this table and in Fig. 1 is the same as that of the paragraph of Section 7 covering that dimension.

PLATE

(*k*) *Thickness of Plate.*—The plate may vary in thickness, but the variation less than that specified shall not exceed $\frac{1}{32}$ in. for each $\frac{1}{8}$ in. in the thickness of the plate.

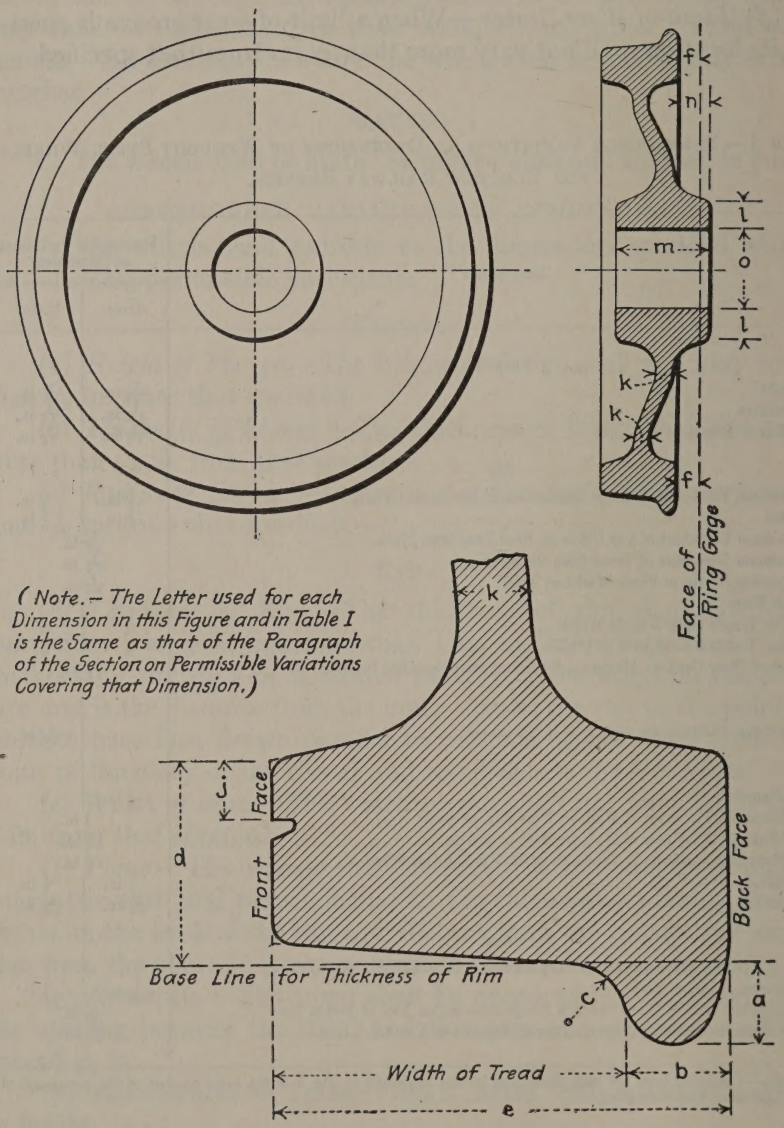


FIG. 1.—Diagram Showing Points at which the Dimensions Covered by Specifications are Measured. For the Permissible Variations in these Dimensions, see Table I or Section 7.

HUB

(*l*) *Diameter of Hub.*—The diameter of hub shall not be less, but may be $\frac{3}{4}$ in. more than that specified. The thickness of wall of the finished bored hub, unless otherwise specified, shall not be less than 1 in. at any point for bores 6 in. or under in diameter, nor less than $1\frac{1}{4}$ in. for bores over 6 in. in diameter. The thickness of the hub wall in any wheel shall not vary more than $\frac{3}{8}$ in. at any two points equi-distant from the face of the hub. **Permissible Variations.**

(*m*) *Length of Hub.*—The length of hub shall not vary more than $\frac{1}{8}$ in. from that specified.

(*n*) *Projection of Hub.*—The projection of the hub beyond the back face of the rim shall not vary more than $\frac{1}{16}$ in. from that specified.

BORE

(*o*) *Diameter of Rough Bore.*—The diameter of rough bore shall not vary more than $\frac{1}{16}$ in. over nor more than $\frac{1}{8}$ in. under that specified. When finished-bore diameter only is specified, the rough-bore diameter shall be made $\frac{1}{4}$ in. less with the permissible variations specified above.

(*p*) *Black Spots in Bore.*—Black spots deeper than $\frac{1}{16}$ in. will not be permitted in rough bore within 2 in. of either face of the hub.

(*q*) *Eccentricity of Bore.*—The eccentricity between the tread at its center line and the rough bore shall not exceed $\frac{3}{64}$ in.

FINISH

8. (*a*) The wheels shall be free from injurious defects and shall have a workmanlike finish. **Finish.**

(*b*) Wheels shall not be offered for inspection if covered with paint, rust or any other substance to such an extent as to hide defects.

MARKING

9. (*a*) The name or brand of the manufacturer, date, and serial number, shall be legibly stamped on each wheel in such a way that the wheel may be readily identified. **Marking.**

(*b*) The tape size shall be legibly marked on each wheel.

INSPECTION AND REJECTION

10. (*a*) The manufacturer shall provide suitable gages and tapes, which shall conform to the contour and dimensions specified. **Inspection.**

(*b*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is

being performed, to all parts of the manufacturer's works which concern the manufacture of the wheels ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the wheels are being furnished in accordance with these specifications. Tests and inspection at the place of manufacture shall be made prior to shipment.

(*c*) The purchaser may make the tests to govern the acceptance or rejection of wheels in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

(*d*) All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection. 11. (*a*) Unless otherwise specified any rejection based on tests made in accordance with Section 10 (*c*) shall be reported within ten working days from receipt of samples.

(*b*) Wheels which show injurious defects while being finished by the purchaser will be rejected, and the manufacturer shall be notified.

Rehearing. 12. Samples tested in accordance with Section 10 (*c*), which represent rejected wheels, shall be preserved for one month from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

STANDARD SPECIFICATIONS
FOR
WROUGHT SOLID CARBON-STEEL WHEELS FOR STEAM RAILWAY SERVICE[1]

Serial Designation: A 57 - 24

These specifications are issued under the fixed designation A 57; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ADOPTED, 1912; REVISED, 1916, 1924.

MANUFACTURE

Process.

1. The steel shall be made by either or both the following processes: open-hearth or electric-furnace.

Discard.

2. A sufficient discard shall be made from each ingot to secure freedom from injurious piping and undue segregation.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

3. The steel shall conform to the following requirements as to chemical composition:

Carbon, per cent	0.65 – 0.85
Manganese, "	0.60 – 0.85
Phosphorous, "	not over 0.05
Sulfur, "	not over 0.05
Silicon, "	not less than 0.15

Ladle Analysis.

4. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements specified in Section 3. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined, together with such identifying records as may be desired, shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 3.

Check Analysis.

5. An analysis may be made by the purchaser from a wheel selected by his representative to represent each melt. The chemical composition thus determined shall conform to the requirements specified in Section 3. Drillings for check analysis shall be taken direct from the plate; or from a slug hot-punched or drilled out of the plate and shall be taken so as not to impair the usefulness of the wheel. A sample may be taken from a single point on the plate, or two samples

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

may be taken from points on radii at right angles to each other. Drillings for check analysis shall be taken by boring entirely through the sample, parallel to the axis of the wheel; they shall be clean and free from scale, oil and other foreign substances. All drillings from any one wheel shall be thoroughly mixed together.

MATING

Mating.

6. (*a*) The wheels shall be mated as to tape sizes and shipped in pairs.

(*b*) When so specified in the purchaser's order, wheels of each type and rough bore diameter in each carload shall be so selected as to permit of mating so that the ladle analysis for any pair shall not show a difference in carbon content exceeding 5 points.

PERMISSIBLE VARIATIONS IN DIMENSIONS[1]

Permissible Variations.

7. The wheels shall conform to the dimensions specified within the following permissible variations.

FLANGE

(*a*) *Height of Flange.*—The height of flange shall not be less but may be $\frac{1}{8}$ in. more than that specified.

(*b*) *Thickness of Flange.*—The thickness of flange shall not vary more than $\frac{1}{16}$ in. from that specified.

(*c*) *Radius of Throat.*—The radius of throat shall not vary more than $\frac{1}{16}$ in. from that specified.

RIM

(*d*) *Thickness of Rim.*—The thickness of the rim shall be measured radially of the wheel on the back face of the rim, and is the distance between the inside diameter of the rim and the point at which the back rim of the wheel is cut by a line drawn parallel to the axis of the wheel through the intersection of the line *A–B*, Fig. 1, and the tread of the wheel.

NOTE.—The line *A–B*, Fig. 1, indicates the plane of the tread circle. In the standard American wheels with rims $5\frac{1}{2}$ in. wide the distance from the line *A–B* to the back face of the rim is $2\frac{7}{8}$ in.

(*e*) Thickness of rim thus measured shall be not less than that specified, and in any one wheel shall not vary more than $\frac{1}{8}$ in.

(*f*) To facilitate measurement of rim thickness, the radius of the inside edge of the back face of rim shall not exceed $\frac{1}{8}$ in. A sharp corner is preferable.

(*g*) The rim thickness measured radially on a plane 1 in. from the

[1] To facilitate the use of the specifications, the various dimensions are illustrated in Fig. 1, and the permissible variations in those dimensions are also given in tabular form in Table I.

front face of the wheel shall not vary more than $\frac{1}{8}$ in. in any one wheel. The contour of the inner surface of the rim shall be practically symmetrical on both sides of the plate.

TABLE I.—PERMISSIBLE VARIATIONS IN DIMENSIONS OF WROUGHT SOLID CARBON-STEEL WHEELS FOR STEAM RAILWAY SERVICE.

Dimensions	Permissible Variations in Dimensions	
	Over	Under
FLANGE		
(*a*) Height	$\frac{1}{8}$ in.	0
(*b*) Thickness	$\frac{1}{16}$ in.	$\frac{1}{16}$ in.
(*c*) Radius of Throat	$\frac{1}{16}$ in.	$\frac{1}{16}$ in.
RIM		
(*e*) 1. Thickness, at Back Face of Wheel	[a]	0
2. Maximum Variation in Rim Thickness at Back Face in any One Wheel	$\frac{1}{8}$ in.	
(*g*) Maximum Variation in Rim Thickness Measured 1 in. from Front Face of Wheel	$\frac{1}{8}$ in.	
(*h*) Inside Diameter of Rim at Back Face of Wheel	[a]	$\frac{3}{8}$ in.
(*j*) Inside Diameter of Rim at Front Face of Wheel in Relation to Inside Diameter at Back Face of Wheel	0	$\frac{1}{4}$ in.
(*k*) Width of Rim	$\frac{1}{8}$ in.	$\frac{1}{8}$ in.
(*l*) Maximum Departure of any Circle on Back Face from Plane	$\frac{1}{16}$ in.	
(*m*) Maximum Departure of Tread from Rotundity	$\frac{1}{16}$ in.	
(*n*) Maximum Height of Block Marks on Tread	$\frac{1}{64}$ in.	
(*o*) Tape Sizes	14	0
PLATE		
(*p*) 1. Thickness, when Minimum Size is Specified	....	0
2. When Desired Thickness is Specified, Variation less than that Specified for each $\frac{1}{8}$ in. of Thickness	....	$\frac{1}{32}$ in
HUB		
(*q*) 1. Diameter	....	[b]
2. Minimum Thickness of Wall, for Bore 7 in. or under	$1\frac{1}{4}$ in.	
3. Minimum Thickness of Wall, for Bore over 7 in.	$1\frac{1}{2}$ in.	
4. Maximum Variation in Thickness of Wall in any One Wheel	$\frac{1}{4}$ in.	
(*r*) Length	$\frac{1}{8}$ in.	$\frac{1}{8}$ in
(*s*) Depression below Front Face of Rim	$\frac{1}{8}$ in.	0
(*t*) Projection beyond Back Face of Rim:		
1. If Finish Machined	0	0
2. If not Finish Machined, Allowance for Finish to be not less than $\frac{1}{16}$ in. nor more than $\frac{3}{16}$ in.		
BORE		
(*u*) Diameter of Rough Bore	$\frac{1}{16}$ in.	$\frac{1}{8}$ in.
(*w*) Maximum Eccentricity of Rough Bore in Relation to Tread	$\frac{3}{64}$ in	

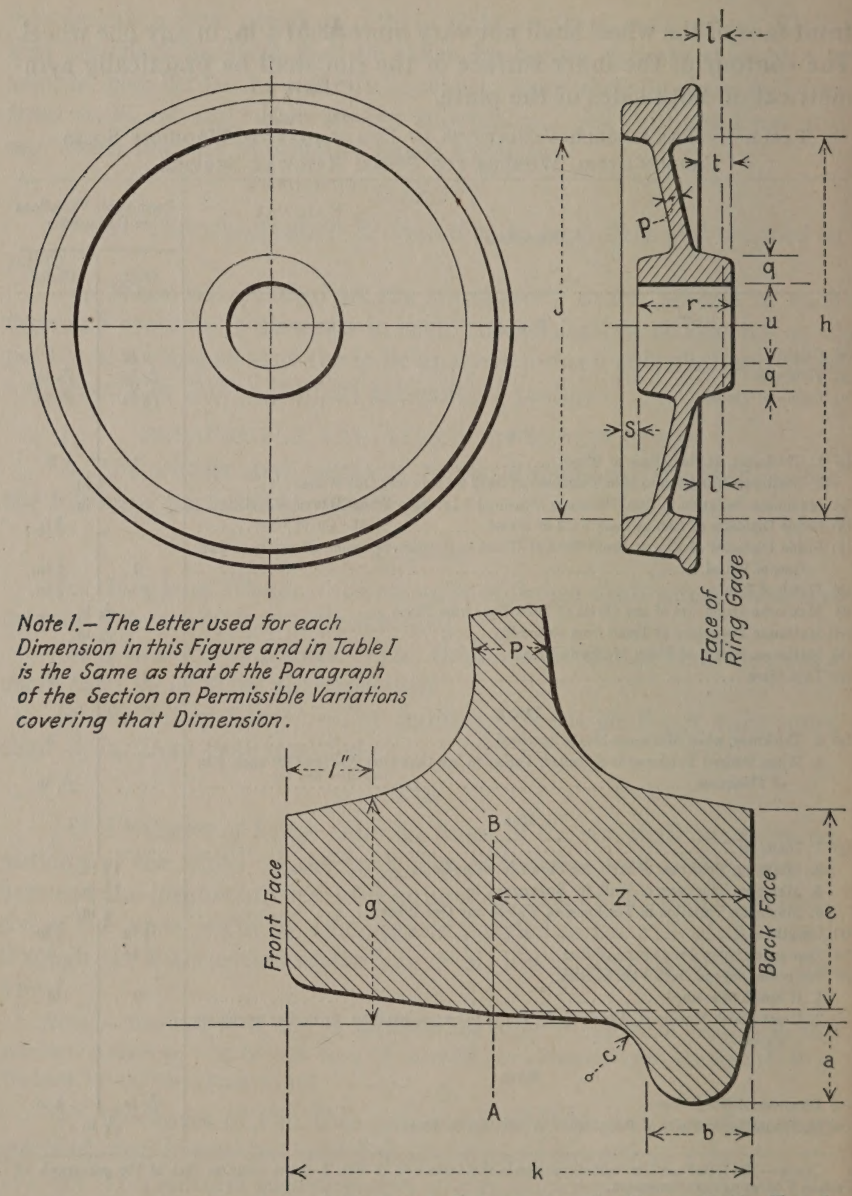
NOTE.—The letter used for each dimension in this table and in Fig. 1 is the same as that of the paragraph of Section 7 covering that dimension.

[a] Limited by tape size.

[b] Limited by wall thickness.

(*h*) The inside diameter of the rim at the back face of the wheel shall not vary more than $\frac{3}{8}$ in. under that specified.

(*j*) *Diameter of Rim.*—The inside diameter of the rim at the front face of the wheel shall not exceed the inside diameter at the back face nor vary under that dimension by more than $\frac{1}{4}$ in.



Note 1.— The Letter used for each Dimension in this Figure and in Table I is the Same as that of the Paragraph of the Section on Permissible Variations covering that Dimension.

Note 2. — The Line A–B indicates the Plane of the Tread Circle. In the Standard Wheels with Rims $5\frac{1}{2}$" wide the Distance Z from the Line A–B to the Back Face of the Rim is $2\frac{7}{8}$".

FIG. 1.—Diagram Showing Points at which the Dimensions Covered by Specifications are Measured. For the Permissible Variations in these Dimensions, see Table I or Section 7.

(*k*) *Width of Rim.*—The width of rim shall not vary more than $\frac{1}{8}$ in. from that specified.

(*l*) *Plane.*—The wheels shall be gaged with a ring gage placed concentric with and perpendicular to the axis of the wheel. For all points on the back face of the rim equi-distant from the center, the variation from the plane of the gage when so placed shall not exceed $\frac{1}{16}$ in.

(*m*) *Rotundity.*—The tread shall be gaged with a ring gage, and the opening between the tread and this gage at any point shall not exceed $\frac{1}{16}$ in.

(*n*) *Block Marks on Tread.*—Block marks shall not exceed $\frac{1}{64}$ in. in height.

(*o*) *Tape Sizes.*—The tape sizes of the wheels shall not be less than that specified, and shall not exceed this by more than 14 tapes.

PLATE

(*p*) *Thickness of Plate.*—The plate may vary in thickness. When the drawings specified with an order show minimum thicknesses for the plate, the plate thickness shall not be less than that shown. When the plate thicknesses shown by the drawings are not specified as minimum, the variation in plate thickness less than that shown by the drawings shall not exceed $\frac{1}{32}$ in. for each $\frac{1}{8}$ in. in the thickness of the plate.

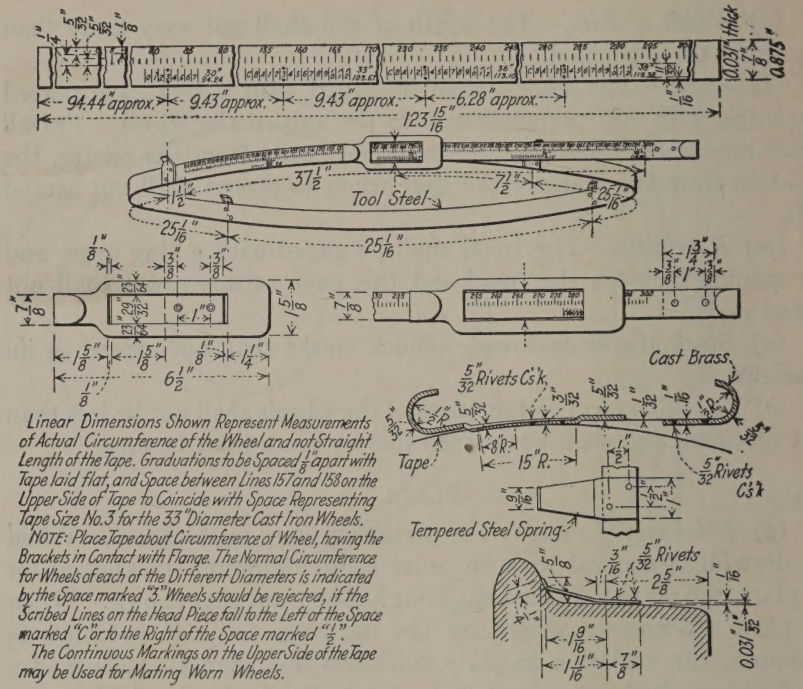
HUB

(*q*) *Diameter of Hub.*—The diameter of hub may vary, but unless otherwise specified the thickness of wall of the finished bored hub shall not be less than $1\frac{1}{4}$ in. at any point for bores 7 in. or under in diameter, nor less than $1\frac{1}{2}$ in. for bores over 7 in. in diameter. The thickness of the hub wall in any wheel shall not vary more than $\frac{1}{4}$ in. at any two points equi-distant from the face of the hub.

(*r*) *Length of Hub.*—The length of hub shall not vary more than $\frac{1}{8}$ in. from that specified.

(*s*) *Depression of Hub.*—For car and tender wheels and wheels of similar design, with journal-box bearing on front face of the hub, the depression of the hub below the front face of the rim shall not be less but may be $\frac{1}{8}$ in. more than that specified.

(*t*) *Projection of Hub.*—For locomotive truck wheels and wheels of similar design with journal-box bearing on back face of the hub, the wheels may be furnished with the back face of the hub smooth machined to the exact specified dimension for the projection of the hub beyond the back face of the rim, or there shall be left on the back face of the hub not more than $\frac{3}{16}$ in. nor less than $\frac{1}{16}$ in. stock for finishing by the purchaser.

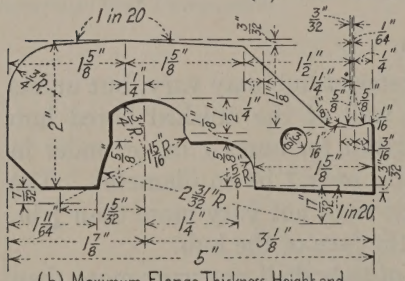


Linear Dimensions Shown Represent Measurements of Actual Circumference of the Wheel and not Straight Length of the Tape. Graduations to be Spaced 1" apart with Tape laid flat, and Space between Lines 157 and 158 on the Upper Side of Tape to Coincide with Space Representing Tape Size No. 3 for the 33" Diameter Cast Iron Wheels.

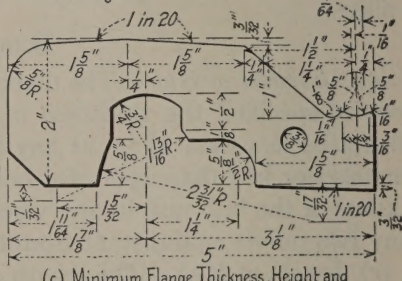
NOTE: Place Tape about Circumference of Wheel, having the Brackets in Contact with Flange. The Normal Circumference for Wheels of each of the Different Diameters is indicated by the Space marked "3." Wheels should be rejected, if the Scribed Lines on the Head Piece fall to the Left of the Space marked "C" or to the Right of the Space marked "1/2".

The Continuous Markings on the Upper Side of the Tape may be Used for Mating Worn Wheels.

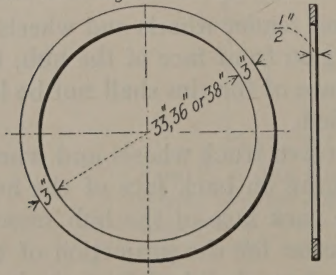
(a). Wheel Circumference Gage.



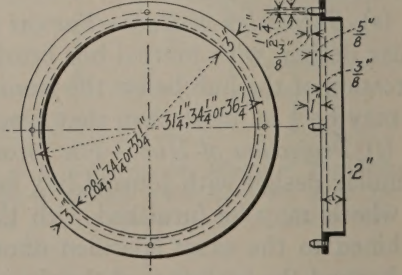
(b). Maximum Flange Thickness, Height and Throat Radius Gage for Solid Steel Wheels.



(c). Minimum Flange Thickness, Height and Throat Radius Gage for Solid Steel Wheels.



(d). Rotundity Gage for 33", 36" or 38" Solid Steel Wheels.



(e). Plane Gage for Wrought Steel Wheels.

FIG. 2.—Standards of American Railway Association, Mechanical Division.

BORE

(*u*) *Diameter of Bore.*—The diameter of rough bore shall not vary more than $\frac{1}{16}$ in. over nor more than $\frac{1}{8}$ in. under the dimensions specified. When not specified, the rough bore shall be $\frac{1}{4}$ in. less in diameter than the finished bore, subject to the above limitations.

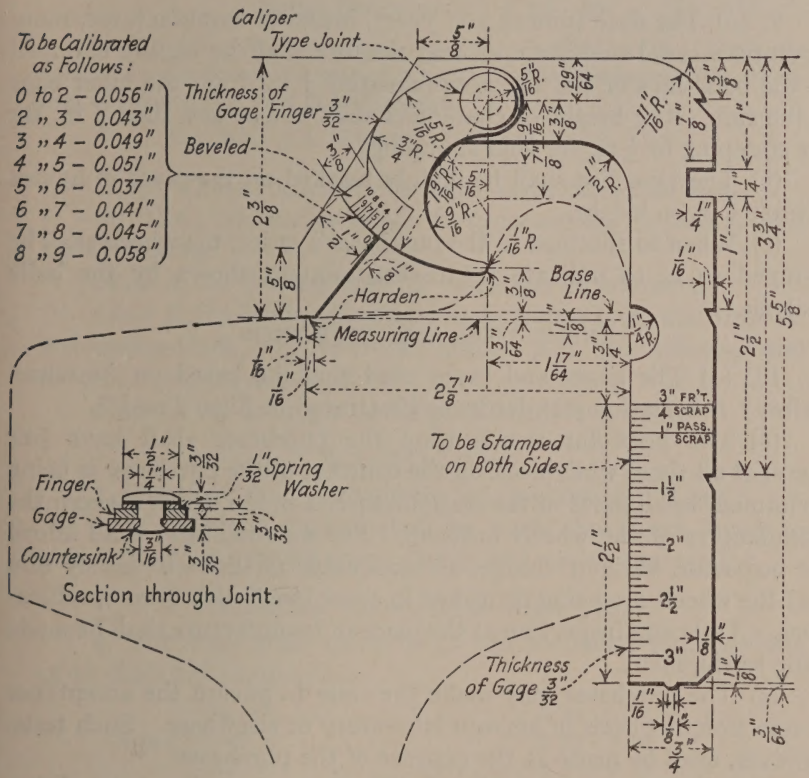


FIG. 3.—Steel Wire Gage of American Railway Association, Mechanical Division. For use in measuring tread thickness, amount of metal to be turned off tread to restore flange contour, and limit of depth and location of witness groove in flange, slid flat spots, vertical flanges, chipped rims and axle collar thickness.

(*v*) *Black Spots in Bore.*—No wheels shall have black spots in the rough bore which will not be completely removed in finish boring.

(*w*) *Eccentricity of Bore.*—The eccentricity between the rough bore and the tread measured in the plane of the tread circle, as indicated by the line *A–B* in Fig. 1, shall not exceed $\frac{3}{64}$ in.

FINISH

Finish.

8. (*a*) The wheels shall be free from injurious defects and shall have a workmanlike finish.

(*b*) Wheels shall not be offered for inspection if covered with paint, rust, or any other substance to such an extent as to hide defects.

MARKING

Marking.

9. (*a*) The date (month and year), brand of manufacturer, manufacturer's serial number and heat number shall be legibly stamped on the back face of the rim approximately $\frac{1}{4}$ in. from the inner edge of the rim. The height of characters shall not be less than $\frac{5}{8}$ in. for hot stamping or $\frac{1}{2}$ in. for cold stamping.

(*b*) The tape size shall be plainly marked on the plate in figures at least 1 in. in height.

(*c*) When so specified in the purchaser's order, the wheels shall be stamped so as to indicate the carbon content shown by the ladle analysis.

INSPECTION AND REJECTION

Inspection.

10. (*a*) The gages and tapes used shall be based on American Railway Association standards, as illustrated in Figs. 2 and 3.

(*b*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the wheels ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the wheels are being furnished in accordance with these specificaitons. Tests and inspection at the place of manufacture shall be made prior to shipment.

(*c*) The purchaser may make the tests to govern the acceptance or rejection of wheels in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

(*d*) All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection.

11. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 10 (*c*) shall be reported within five working days from the receipt of samples.

(*b*) Wheels which show injurious defects while being finished by the purchaser will be rejected, and the manufacturer shall be notified.

Rehearing.

12. Samples tested in accordance with Section 10 (*c*), which represent rejected wheels, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

STANDARD SPECIFICATIONS
FOR
STEEL TIRES[1]

Serial Designation: A 26 – 16

These specifications are issued under the fixed designation A 26; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ADOPTED, 1901; REVISED, 1909, 1913, 1914, 1916.

Scope.

1. (*a*) These specifications cover three classes of tires.

(*b*) The purposes for which these classes are frequently used are as follows:

Class A, for driving tires for passenger locomotives;

Class B, for driving tires for freight locomotives and tires for locomotive-truck, tender-truck, trailer and car wheels, and miscellaneous service;

Class C, for driving tires for switching locomotives.

MANUFACTURE

Process.

2. The steel shall be made by the open-hearth process.

Discard.

3. A sufficient discard shall be made from each ingot to secure freedom from injurious piping and undue segregation.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

4. The steel shall conform to the following requirements as to chemical composition:

Carbon	Class A	0.50 – 0.70 per cent
	Class B	0.60 – 0.80 "
	Class C	0.70 – 0.85 "
Manganese		not over 0.75 "
Phosphorus		" " 0.05 "
Sulfur		" " 0.05 "
Silicon		0.15 – 0.35 "

Ladle Analyses.

5. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements specified in Section 4. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

or his representative, and shall conform to the requirements specified in Section 4.

Check Analyses. 6. An analysis to represent each melt may be made by the purchaser from turnings taken from a tire or from a tension test specimen, if the rension test is specified. The chemical composition thus determined shall conform to the requirements specified in Section 4.

PHYSICAL PROPERTIES AND TESTS

Tension Tests. 7. If tension tests from representative bars in accordance with Section 8 are specified by the purchaser, the tensile properties shown shall conform to the following minimum requirements:

	Class A.	Class B.	Class C
Tensile strength, lb. per sq. in.....	105 000	115 000	125 000
Elongation in 2 in., per cent.....	12	10	8
Reduction of area, "	16	14	12

Tension Test Specimens. 8. (*a*) The tension test specimen representing each melt shall be taken from a test ingot taken during the pouring of the melt, and shall have received approximately the same amount of work as the tires which it represents.

(*b*) The specimens shall conform to the dimensions shown in Fig. 1. The ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial.

Number of Tests. 9. (*a*) If specified by the purchaser, one tension test shall be made from each melt.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any test specimen is less than that specified in Section 7 and any part of the fracture is more than $\frac{3}{4}$ in. from the center of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

Retests. 10. If the results of the tension test for any melt do not conform to the requirements of Section 7, a retest may be made on a specimen cut from a tire of the same melt furnished at the expense of the manufacturer. This retest shall give results conforming to the requirements of Section 7.

MATING

Mating. 11. The tires shall be grouped as to outside diameters and shipped in sets.

PERMISSIBLE VARIATIONS IN DIMENSIONS

12. Tires may be furnished with all surfaces as rolled, and shall conform to the dimensions specified within the following permissible variations: Permissible Variations.

(*a*) *Height of Flange.*—The height of flange shall not vary more than $\frac{3}{32}$ in. from that specified.

(*b*) *Thickness of Flange.*—The thickness of flange shall not vary more than $\frac{1}{16}$ in. from that specified.

(*c*) *Radius of Throat.*—The radius of throat shall not vary more than $\frac{1}{8}$ in. over nor more than $\frac{1}{16}$ in. under that specified.

(*d*) *Width of Tire.*—The width of tire shall not vary more than $\frac{1}{8}$ in. over nor more than $\frac{1}{16}$ in. under that specified.

(*e*) *Inside Diameter.*—The rough inside diameter shall not be more, but may be $\frac{1}{4}$ in. less than that specified. When

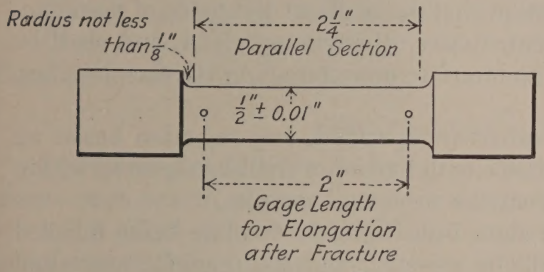

Radius not less than 1/8"
2 1/4"
Parallel Section
1/2" ± 0.01"
2"
Gage Length for Elongation after Fracture
Note:-The Gage Length, Parallel Section, and Fillets shall be as Shown, but the Ends may be of any Shape to fit the Holders of the Testing Machine in such a Way that the Load shall be axial.

FIG. 1.

finished inside diameter only is specified, the rough diameter shall be from $\frac{3}{16}$ to $\frac{7}{16}$ in. less than this diameter.

(*f*) *Outside Diameter.*—Unless otherwise specified, the outside diameter when 54 in. or under shall not be less, but may be $\frac{1}{2}$ in. more than that specified; and when over 54 in. shall not vary more than $\frac{1}{8}$ in. under nor more than $\frac{3}{8}$ in. over that specified.

(*g*) *Set Diameters.*—The tires shall be furnished in sets and the variation in outside diameters in each set shall not exceed $\frac{1}{16}$ in. for tires 33 in. or under in outside diameter, nor exceed $\frac{3}{32}$ in. for tires over 33 in. in outside diameter.

(*h*) *Rotundity.*—Tires shall not be out of round more than $\frac{1}{16}$ in. for tires 33 in. or under in outside diameter, nor more than $\frac{3}{32}$ in. for tires over 33 in. in outside diameter.

FINISH

13. The tires shall be free from injurious defects and shall have a workmanlike finish. Finish.

MARKING

Marking

14. The name or brand and serial number of the manufacturer shall be legibly stamped on the tire close to the inside edge, where they will not be removed at the last turning. Set numbers shall be legibly stenciled on each tire.

INSPECTION AND REJECTION

Inspection.

15. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the tires ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the tires are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection.

16. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 6 shall be reported within five working days from the receipt of samples.

(*b*) Tires which show injurious defects while being finished by the purchaser will be rejected, and the manufacturer shall be notified.

Rehearing.

17. Samples tested in accordance with Section 6, which represent rejected tires, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

STANDARD SPECIFICATIONS FOR STEEL CASTINGS[1]

Serial Designation: A 27 – 24

These specifications are issued under the fixed designation A 27; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ADOPTED, 1901; REVISED, 1905, 1912, 1913, 1914, 1916, 1921, 1924.

Scope.

1. These specifications cover steel castings for general service and for ships. Two classes of castings are covered: namely,

Class A, castings for which no physical requirements are specified.

Class B, castings for which physical requirements are specified. These are of three grades: hard, medium, and soft.

MANUFACTURE

Process.

2. The steel shall be made by one or more of the following processes: open-hearth, electric furnace, converter, or crucible.

Heat Treatment.

3. (*a*) Class A castings need not receive any heat treatment unless so specified, or unless the carbon content exceeds 0.30 per cent.

(*b*) Class A castings in which the carbon content is over 0.30 per cent and all Class B castings shall receive a heat treatment proper to the design and chemical composition of the castings.

(*c*) Heat treatment, unless otherwise specified by the purchaser, may consist of annealing, or of normalizing, or of normalizing followed by annealing, or of normalizing followed by a draw-back to a temperature below the critical range. No castings which have been quenched in any liquid medium shall be offered under these specifications.

(*d*) *Annealing.*—The procedure for annealing shall consist in allowing the castings to cool after pouring, to a temperature below the critical range. They shall then be uniformly reheated to the proper temperature to refine the grain, and allowed to cool uniformly in the furnace.

(*e*) *Normalizing.*—The procedure for normalizing shall consist in allowing the castings to cool after pouring, to a temperature below the critical range. They shall then be reheated to the proper temperature to refine the grain and allowed to cool in still air.

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

4. The castings shall conform to the following requirements as to chemical composition:

		Class A.	Class B.
Carbon		not over 0.45 per cent	....
Phosphorus	Acid	" " 0.07 "	not over 0.06 per cent
	Basic	" " 0.06 "	" " 0.05 "
Sulfur		....	" " 0.06 "

Ladle Analyses.

5. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements specified in Section 4. This analysis shall be made from drillings taken at least $\frac{1}{4}$ in. beneath the surface of a test ingot obtained during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 4.

Check Analyses.

6. (*a*) Analyses of Class A castings may be made by the purchaser. The phosphorus content thus determined shall not exceed that specified in Section 4 by more than 20 per cent. Samples for analysis shall be taken not less than $\frac{1}{4}$ in. beneath the surface, and in such a way as not to destroy the castings.

(*b*) Analyses of Class B castings may be made by the purchaser from a broken tension test specimen. The phosphorus and sulfur content thus determined shall not exceed that specified in Section 4 by more than 20 per cent.

PHYSICAL PROPERTIES AND TESTS

(For Class B Castings only.)

Tension Tests.

7. (*a*) The castings shall conform to the following minimum requirements as to tensile properties:[1]

	Hard.	Medium.	Soft.
Tensile strength, lb. per sq. in..	80 000	70 000	60 000
Yield point, lb. per sq. in.....	0.45 tens. str.	0.45 tens. str.	0.45 tens. str.
Elongation in 2 in., per cent...	17	20	24
Reduction of area, " ...	25	30	35

(*b*) The yield point shall be determined by the drop of the beam of the testing machine.

Bend Tests.

8. (*a*) Bend tests shall not be required for castings of the hard grade, and shall be required for castings of the medium and soft grades only when so specified in the order.

[1] Because it has come to the attention of Committee A-1 on Steel that the intent of the requirement of Section 7 (*a*) has at times been misinterpreted, the committee wishes to make it clear that it is not intended that maximum limits shall be placed on the tensile strength in any of the grades specified.

(*b*) When a bend test is specified, the test specimen shall withstand being bent cold without cracking on the outside of the bent portion, around a pin 1 in. in diameter to the following angles:

	HARD.	MEDIUM.	SOFT.
Angle of bend.....	No Bend Test	90 deg.	120 deg.

Alternative Tests to Destruction.

9. The tensile properties of the castings shall be determined from test bars unless in the case of castings weighing not over 150 lb. the manufacturer desires to offer, as an alternative, tests to destruction. Upon agreement with the inspector, the castings shall be grouped in lots, each lot containing castings from the same melt and from the same heat-treatment charge, and the inspector shall select from each lot one casting to represent the lot. The representative

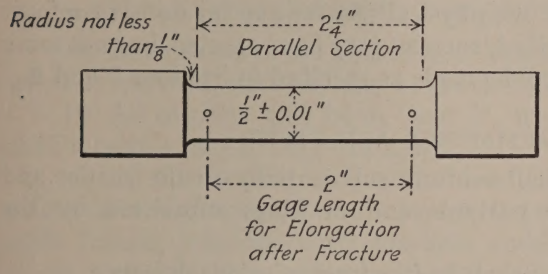

Radius not less than 1/8"
2 1/4"
Parallel Section
1/2" ± 0.01"
2"
Gage Length for Elongation after Fracture
Note:-The Gage Length, Parallel Section, and Fillets shall be as Shown, but the Ends may be of any Shape to fit the Holders of the Testing Machine in such a Way that the Load shall be axial.

FIG. 1

casting shall be tested to destruction as a substitute for the tension test. This test shall show the material to be ductile and free from injurious defects.

Test Specimens.

10. (*a*) Tension and bend test specimens shall be taken from test bars cast attached to the castings where practicable. If the design of the castings is such that test bars should not be attached to the castings, the test bars shall be cast attached to special blocks, of which a sufficient number shall be provided for each lot of castings. Test bars from which tension and bend test specimens are to be taken shall remain attached to the castings or blocks they represent through heat treatment and until presented for inspection. Test bars shall be provided in sufficient numbers to furnish the tests required in Section 11.

(*b*) If satisfactory to the manufacturer and inspector, tension test specimens may be cut from heat-treated castings instead of from test bars.

(*c*) Tension test specimens shall conform to the dimensions shown in Fig. 1. The ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial.

Bend Test Specimens.

(*d*) Bend test specimens shall be machined to 1 by $\frac{1}{2}$ in. in section with the corners rounded to a radius of not over $\frac{1}{16}$ in.

Number of Tests.

11. (*a*) One tension test and, when specified, one bend test shall be made from each melt in each heat-treatment charge and, when specified, from each casting weighing 500 lb. or over.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded; in which case another specimen from the same lot shall be substituted.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 7 (*a*) and any part of the fracture is more than $\frac{3}{4}$ in. from the center of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

Retests.

12. If the results of the physical test for any lot do not conform to the requirements specified, such lot may be re-treated, but not more than twice. Retests shall be made as specified in Sections 7 and 8.

WORKMANSHIP AND FINISH

Workmanship.

13. The castings shall conform substantially to the shapes and sizes indicated by the patterns and drawings submitted by the purchaser.

Finish.

14. (*a*) The castings shall be free from injurious defects.

Welding.

(*b*) Defects which do not impair the strength of the castings may be welded by an approved process. The defects shall be cleaned out to solid metal, before welding, and when so required by the inspector, shall be submitted to him in this condition for his approval. When required by the inspector, important castings shall be heat treated after welding.

INSPECTION AND REJECTION

Inspection.

15. (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the castings ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the castings are being furnished in accordance with these specifications.

(*b*) If, in the case of important castings for special purposes, surface inspection in the green state is required, this shall be so specified in the order.

(*c*) All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment unless otherwise

specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection.

16. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 6 shall be reported within five working days from the receipt of samples.

(*b*) Castings which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected and the manufacturer shall be notified.

Rehearing.

17. Samples tested in accordance with Section 6, which represent rejected castings, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

SPECIAL REQUIREMENTS FOR CASTINGS FOR SHIPS

Castings for Ships.

18. In addition to the preceding requirements, castings for ships, when so specified, shall conform to the following requirements:

Heat Treatment.

19. All castings shall be of Class B, medium or soft grade, and shall receive a proper heat treatment.

Number of Tests.

20. (*a*) One tension and one bend test shall be made from each of the following castings: stern frames, stern posts, twin screw spectacle frames, propeller shaft brackets, rudders, steering quadrants, tillers, stems, anchors, and other castings when specified.

(*b*) When a casting is made from more than one melt, four tension and four bend tests shall be made from each casting.

Percussion Tests.

21. (*a*) A percussion test shall be made on each of the following castings: stern frames, stern posts, twin screw spectacle frames, propeller shaft brackets, rudders, steering quadrants, tillers, stems, anchors, and other castings when specified.

(*b*) For this test, the casting shall be suspended by chains and hammered all over with a hammer of a weight approved by the purchaser or his representative. If cracks, flaws, defects, or weakness appear after such test, the casting may be rejected.

STANDARD SPECIFICATIONS
FOR
CARBON-STEEL CASTINGS FOR RAILROADS[1]

Serial Designation: A 87 – 27

These specifications are issued under the fixed designation A 87; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1922; ADOPTED IN AMENDED FORM, 1927.

Scope.

1. (*a*) These specifications cover all carbon-steel castings for locomotive and car equipment, and for miscellaneous use, classified as Grade A and Grade B.

(*b*) The purposes for which the two grades are generally used are:

Grade A, unannealed, covers only such special castings as may be approved by the purchaser. *Grade A*, annealed, covers such castings not covered by Grade A, unannealed.

Grade B covers all castings for high stresses such as truck side frames, bolsters, couplers and coupler parts, locomotive frames and locomotive driving and trailer wheel centers.

Basis of Purchase.

2. Grade A castings shall be furnished annealed unless otherwise specified by the purchaser.

Grade B castings shall be furnished annealed.

MANUFACTURE

Process.

3. The steel may be made by one or more of the following processes: open-hearth, electric-furnace, crucible or converter.

Annealing.

4. (*a*) The castings shall be allowed to become cool. They shall then be uniformly heated to the proper temperature to refine the grain, and allowed to cool uniformly.

Annealing Lugs.

(*b*) For the purpose of determining the quality of annealing of all castings weighing 150 lb. or over, and of such lighter castings as shall be required by the purchaser or his representative, there shall be provided for removal by the inspector after annealing and also after reannealing, if necessary, at least one and not more than two annealing lugs. The location of the annealing lugs shall be such that

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

when removed by the inspector they shall be indicative of the character of annealing. The standard annealing lug shall be 1 in. in height and 1 in. in width and $\frac{5}{8}$ in. in thickness where it joins the casting.

(*c*) If, in the opinion of the inspector, a casting is not properly annealed, he may at his option require the casting to be re-annealed.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

5. The steel shall conform to the following requirements as to chemical composition:

	GRADE A	GRADE B
Manganese, per cent, not over	0.85	0.85
Phosphorus, per cent, not over	0.05	0.05
Sulfur, per cent, not over	0.05	0.05

Ladle Analyses.

6. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus, sulfur and silicon. This analysis shall be made from drillings taken at least $\frac{1}{4}$ in. beneath the surface of a test ingot obtained during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, when requested, and shall conform to the requirements specified in Section 5.

Check Analyses.

7. An analysis may be made by the purchaser from the broken tension test specimen or from a casting representing each melt. The chemical composition thus determined shall conform to the requirements specified in Section 5. Drillings for analysis shall be taken not less than $\frac{1}{4}$ in. beneath the surface, and shall be taken in such a manner as not to impair the usefulness of a casting.

PHYSICAL PROPERTIES AND TESTS

Tension Tests.

8. (*a*) The steel shall conform to the following minimum requirements as to tensile properties:

	GRADE A		GRADE B
	UNANNEALED	ANNEALED	ANNEALED
Yield point, lb. per sq. in.	29 250	29 250	36 000
Elongation in 2 in., per cent.	1 450 000	1 600 000	1 600 000
	Tens. str.	Tens. str.	Tens. str.
but in no case less than	22	24	22
Reduction of area, per cent	2 250 000	2 600 000	2 500 000
	Tens. str.	Tens. str.	Tens. str.
but in no case less than	30	35	30

(*b*) The tensile strength shall be reported as information.

(*c*) The yield point shall be determined by the drop of the beam or by the dividers, the method being optional with the inspector, and

at a cross-head speed not to exceed $\frac{1}{8}$ in. per minute. The tensile strength shall be determined at a speed not to exceed $1\frac{1}{2}$ in. per minute.

Test Specimens.

9. (*a*) A sufficient number of test coupons, from which the required test specimen may be prepared, shall be cast attached in the neighborhood of each end of each locomotive frame, attached to each locomotive cylinder, to each wheel center, and to miscellaneous castings weighing over 150 lb. These test coupons shall remain attached to the castings throughout the annealing and until the castings are presented for inspection. If the design of the casting is such that the test coupons cannot be attached, they shall be cast in runners outside of the casting, but attached to it, to represent each melt. The location of the test coupons, as well as the method of casting such coupons, shall be subject to mutual agreement between the inspector and the manufacturer. In the case of any orders for

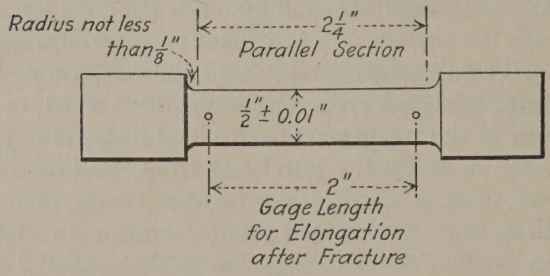

Radius not less than 1/8"
2 1/4"
Parallel Section
1/2" ± 0.01"
2"
Gage Length for Elongation after Fracture
Note:-The Gage Length, Parallel Section, and Fillets shall be as Shown, but the Ends may be of any Shape to fit the Holders of the Testing Machine in such a Way that the Load shall be axial.

FIG. 1.

castings weighing under 150 lb., the physical properties as required in Section 8, may be determined from an extra or spare test bar cast with and attached to some other casting from the same melt.

(*b*) When sufficient coupons have not been cast, a test specimen may be cut from a finished casting at a location mutually agreed upon by the inspector and the manufacturer.

(*c*) Tension test specimens shall conform to dimensions shown in Fig. 1. The ends shall be not less than $\frac{7}{8}$ in. in diameter and of a length and form to fit the holders of the testing machine in such a way that the load shall be axial.

Number of Tests.

10. (*a*) One tension test shall be made from the neighborhood of each end of each locomotive frame and both tests shall meet the requirements of the specifications. One tension test may be made from each wheel center and each locomotive cylinder casting, but of such castings at least one of each kind in each melt shall be tested. For miscellaneous castings from melts which do not include frames, wheel

centers or cylinders, one tension test shall be made from each melt, except as provided in Section 11 (*a*).

(*b*) If the test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 8 and any part of the fracture is more than $\frac{3}{4}$ in. from the center of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

(*d*) No part of these specifications shall operate to cause any one tension test to apply to more than 40 tons of castings as offered for inspection.

Number of Tests, Consecutive Melts of Miscellaneous Castings.

11. (*a*) After 15 consecutive melts, which may contain any or all classes of castings (except frames, wheel centers, and cylinders) covered by these specifications on one or more orders have been tested and accepted in accordance with the above requirements, the manufacturer may group the succeeding melts in lots of five melts each, but each lot not to exceed 40 tons, the entire group to be accepted if the test specimen selected from the lot fulfills the chemical and physical requirements herein specified. If this test fails, a rehearing will be granted on the melt that the failed bar represents, and the other four melts of the group shall be tested individually.

(*b*) If there is a period of more than six months between shipments of the class of castings covered by these specifications, then each melt shall be tested individually until 15 consecutive melts have been accepted, after which the melts may again be grouped as in Paragraph (*a*).

(*c*) If one or more melts are rejected, each succeeding melt shall be tested individually until 15 consecutive melts have been accepted, after which melts may again be grouped as in Paragraph (*a*).

Number of Tests, Small Orders.

12. In case of small orders for bolsters, truck sides, draft arms, yokes or castings weighing over 150 lb. where the size of the order and the available pattern and foundry equipment are such that not more than five castings can be cast in any one melt, the physical properties, as required in Section 8, will be determined from an extra or spare test coupon cast with and attached to some other casting of the same melt.

Retests.

13. If the results of the physical test lot do not conform to the requirements specified, the manufacturer may re-anneal such lot not more than twice and retest shall be as specified in Section 8.

Alternative Tests to Destruction.

14. In the case of orders including only castings not exceeding 150 lb. in weight, a test to destruction of one casting from each 100

castings or smaller lot may be substituted for the tension tests, at the option of the inspector. This test shall show the material to be ductile, free from injurious defects, and suitable for the purpose intended.

WORKMANSHIP AND FINISH

Workmanship.

15. The castings shall substantially conform to the sizes and shapes shown on the purchaser's drawings, and shall be made in a workmanlike manner.

Finish.

16. (*a*) The castings shall be free from injurious defects.

(*b*) Minor defects which do not impair the strength of the castings may, with the approval of the inspector, be welded by an approved process. The defects shall first be cleaned out to solid metal; and after welding, the castings shall be annealed, if required by the inspector.

MARKING

Marking.

17. The manufacturer's name or indentification mark and the specified pattern number shall be cast on all castings. In addition, the month and year when made shall be cast on all bolsters, truck sides, frames, wheel centers, cylinders, and similar castings. The location and size of numbers shall be agreed upon by the manufacturer and the inspector. In accordance with the standard practice of the individual foundry to identify individual castings, a serial number may be cast or the melt number may be stamped on bolsters, truck sides, frames, wheel centers, cylinders and similar castings as agreed upon by the manufacturer and the inspector. The melt number shall be legibly stamped on all other castings weighing over 150 lb.

INSPECTION AND REJECTION

Inspection.

18. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of castings ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the castings are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection.

19. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 7 shall be reported within five working days from the receipt of samples.

(*b*) Castings which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

Rehearing.

20. Samples tested in accordance with Section 7, which represent rejected castings, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

STANDARD SPECIFICATIONS
FOR
LAP-WELDED AND SEAMLESS STEEL AND LAP-WELDED IRON BOILER TUBES[1]

Serial Designation: A 83 – 27

These specifications are issued under the fixed designation A 83; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1921; ADOPTED IN AMENDED FORM, 1924; REVISED, 1927.

Scope.

1. These specifications cover lap-welded and seamless steel and lap-welded iron boiler tubes, boiler flues, superheater tubes, safe ends and arch tubes.

MANUFACTURE

Process.

2. (*a*) The material for lap-welded tubes shall be made by the open-hearth process, or by the knobbled, hammered charcoal iron process.

(*b*) The material for seamless tubes shall be made by the open-hearth process.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

3. (*a*) Chemical analysis will not be required for charcoal-iron tubes.

(*b*) Material made by the open-hearth process shall conform to the following requirements as to chemical composition:

	Grade A.	Grade B.
Carbon, per cent	0.08 – 0.18	not over 0.03
Manganese, "	0.30 – 0.60	" " 0.03
Phosphorus, "	not over 0.04	" " 0.02
Sulfur, "	" " 0.045	" " 0.045

Check Analyses.

4. (*a*) Analyses of two tubes in each lot of 250 tubes or less, and of 2000 feet or less of safe-end material, may be made by the pur-

[1] Under the standardization procedure of the Society, these specifications are under the joint jurisdiction of the A.S.T.M. Committees A-1 on Steel and A-2 on Wrought Iron.

chaser. The chemical composition thus determined shall conform to the requirements specified in Section 3 (*b*). Drillings for analysis shall be taken from several points around each tube.

(*b*) If the analysis of only one tube does not conform to the requirements specified, analyses of two additional tubes from the same lot shall be made, each of which shall conform to the requirements specified.

PHYSICAL PROPERTIES AND TESTS

5. Tubes of material made by the open-hearth process shall meet the tests specified for steel tubes. Flange Tests.

6. (*a*) For tubes not more than 6 in. in diameter and having a thickness less than 10 per cent of the outside diameter, provided the thickness does not exceed No. 6 B.w.g. (0.203 in.), a test specimen not less than 4 in. in length shall have a flange turned over at right

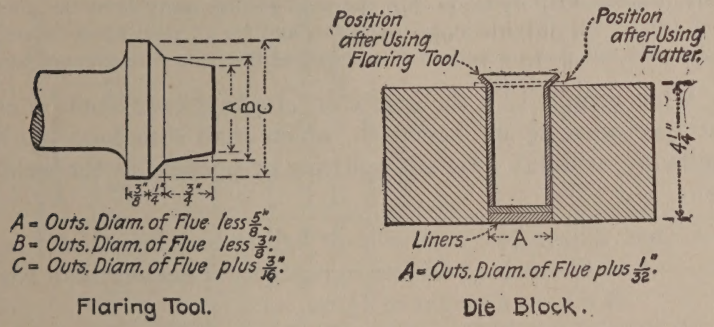


FIG. 1.

angles to the body of the tube without cracking or showing any flaw. This flange, as measured from the outside of tube, shall in no case be less than $\frac{1}{8}$ in. nor more than $\frac{1}{2}$ in. Within these limits the width of flange shall be not less than 12.5 per cent of the outside diameter for charcoal-iron, nor less than 15 per cent for steel tubes up to $2\frac{1}{2}$ in., inclusive. For iron and steel tubes over $2\frac{1}{2}$ in. in diameter and up to $3\frac{3}{4}$ in., inclusive, the width of the flange shall be $\frac{3}{8}$ in., and for tubes over $3\frac{3}{4}$ in., the width of flange shall be 10 per cent of the outside diameter.

(*b*) For tubes not specified in Paragraph (*a*) the flange test will not be required.

(*c*) In making the flange test, it is recommended that the flaring tool and die block as shown in Fig. 1 be used.

7. (*a*) For all tubes, except when the wall thickness is in excess of 10 per cent of the outside diameter, providing the thickness does not exceed No. 6 B.w.g. (0.203 in.), a test specimen 3 in. in length Flattening Test.

shall withstand flattening between parallel plates, without cracking or showing any flaw, until the distance between the plates is as follows:

Three times the wall thickness for seamless tubes;
Five times the wall thickness for lap-welded tubes.

NOTE.—In the case of lap-welded tubes, the test shall be made with the weld at the point of maximum bend.

(*b*) For all tubes not specified in Paragraph (*a*) a test specimen 3 in. in length shall withstand flattening between parallel plates, without cracking or showing any flaw, until the distance between the plates is as follows:

Four times the wall thickness for seamless tubes;
Six times the wall thickness for lap-welded tubes.

NOTE.—In the case of lap-welded wrought-iron tubes thicker than No. 6 B. w. g. (0.203 in.), the test shall be made with the weld 45 deg. away from the point of maximum bend. For other wrought-iron tubes and for all steel tubes covered by this section, the test shall be made with the weld at the point of maximum bend.

Crush Tests.

8. When required by the inspector, crushing tests shall be made on test specimens $2\frac{1}{2}$ in. in length, which shall withstand crushing longitudinally, without cracking, splitting or opening at the weld, as follows:

Steel tubes: No. 10 B.w.g. or lighter to a height of $\frac{3}{4}$ in. or until outside folds are in contact; if heavier than No. 10 B.w.g. to a height of $1\frac{1}{4}$ in.

Charcoal-iron tubes: No. 10 B.w.g. or lighter, to a height of $1\frac{1}{8}$ in.; if heavier than No. 10 B.w.g., to a height of $1\frac{1}{2}$ in. Slight surface checks shall not be a cause for rejection.

Hydrostatic Tests.

9. Tubes under 5 in. in diameter shall withstand an internal hydrostatic pressure of 1000 lb. per sq. in. and tubes 5 in. or over in diameter shall withstand an internal hydrostatic pressure of 800 lb. per sq. in.; provided that the fiber stress corresponding to these pressures does not exceed 16,000 lb. per sq. in. Should the fiber stress corresponding to these pressures exceed 16,000 lb. per sq. in., the test pressure shall be determined by the formula:

$$P = \frac{32{,}000\ t}{D}$$

in which P = the pressure in pounds per square inch, t = the thickness of wall in inches, and D = the outside diameter of the tube in inches.

TABLE I.—STANDARD WEIGHTS OF LAP-WELDED AND SEAMLESS BOILER TUBES.

INCLUDING SAFE ENDS, ARCH TUBES AND LARGE BOILER TUBES.

THICKNESS.		WEIGHT, LB. PER FT. OF LENGTH. Outside Diameter, in.																						
B.w.g.	In.	1 3/4	2	2 1/4	2 1/2	2 3/4	3	3 1/4	3 1/2	3 3/4	4	4 1/2	5	5 1/4	5 3/8	5 1/2	6	7	8	9	10	11	12	13
13	0.095	1.679	1.932	2.186	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
12	0.109	1.910	2.201	2.492	2.783	3.074	3.365	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
11	0.120	2.089	2.409	2.729	3.050	3.370	3.691	4.011	4.331	4.652	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
10	0.134	2.312	2.670	3.028	3.386	3.743	4.101	4.459	4.817	5.175	5.532	6.248	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
9	0.148	2.532	2.927	3.322	3.717	4.112	4.508	4.903	5.298	5.693	6.088	6.879	7.669	8.064	8.262	8.459	.....	.....	.....	.....	.....	.....	.....	.....
8	0.165	.....	3.233	.....	4.114	4.555	4.995	5.436	5.877	6.317	6.758	7.639	8.520	8.960	9.181	9.401	10.282	12.044	13.807	.....	.....	.....	.....	.....
7	0.180	.....	.....	.....	4.460	4.940	5.421	5.901	6.382	6.863	7.343	8.304	9.266	9.746	9.987	10.227	11.188	13.110	15.033	16.955	.....	.....	.....	.....
6	0.203	.....	.....	.....	4.980	5.522	6.064	6.606	.....	.....	8.232	9.316	10.400	.....	.....	.....	12.568	14.736	16.904	19.072	21.240	.....	.....	.....
5	0.220	.....	.....	.....	5.357	5.944	6.531	7.119	.....	.....	.....	.....	11.231	.....	.....	.....	13.580	15.930	18.280	20.629	22.979	25.329	.....	.....
4 1/2	0.229	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	28.788	.....
4	0.238	.....	.....	.....	5.749	6.385	7.020	7.656	.....	.....	.....	.....	.....	.....	.....	.....	14.646	17.188	19.730	22.271	24.813	27.355	.....	32.439
3 1/2	0.2485	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	31.188	.....
3	0.259	.....	4.815	5.507	6.198	6.890	7.582	8.273	8.965	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	24.179	26.945	29.711	.....	35.243
2 1/2	0.2715	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	34.008	.....
2	0.284	.....	.....	.....	6.721	.....	8.238	8.996	9.754	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	29.470	32.503	.....	38.569
1 1/2	0.292	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	36.512	.....
1	0.300	.....	.....	.....	7.048	7.849	8.650	9.451	10.252	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	34.283	.....	40.69
1/2	0.320	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	39.918	.....
0	0.340	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	45.971

NOTE.—Seamless tubes are at present not available above 6 in. in outside diameter.

Lap-welded tubes shall be struck near both ends, while under the test pressure, with a 2-lb. steel hand hammer or the equivalent.

Etch Tests for Charcoal-Iron Tubes.

10. A cross-section of charcoal-iron tubes may be turned or ground to a true surface, polished free from dirt or cracks, and etched[1] until the soft parts are sufficiently dissolved for the iron tube to show a decided ridged surface, with the weld very distinct, while a steel tube would show a homogeneous surface.

Test Specimens.

11. Test specimens shall be taken from finished tubes. They shall be smooth on the ends and free from burrs. All specimens shall be tested cold.

Number of Tests.

12. Each tube shall be subjected to the hydrostatic test. One of each of the physical tests specified shall be made from each of two tubes in each lot of 250 or less, and each 2000 feet or less of safe end material.

Retests.

13. If the results of the physical tests of only one tube from any lot do not conform to the requirements specified in Sections 6, 7 and 8, retests of two additional tubes from the same lot shall be made, each of which shall conform to the requirements specified.

STANDARD WEIGHTS

Standard Weight.

14. The standard weights for tubes of various outside diameters and thicknesses are as indicated in Tables I and II.

Permissible Variation.

15. The weight of any tube shall not be less than that shown in Tables I and II.

WORKMANSHIP AND FINISH

Workmanship.

16. (*a*) Finished tubes 4 in. or under in outside diameter shall be circular within 0.02 in. and the mean outside diameter shall not vary more than 0.015 in. from the size ordered. For tubes over 4 in. in outside diameter, these variations shall not exceed 0.5 per cent of the outside diameter.

(*b*) Tubes shall be gaged with a Birmingham wire gage, and shall be not less than the thickness specified, except that tubes will be accepted on which the gage will go on tightly at the thinnest point.

(*c*) Cold-drawn tubes shall not, at any place, exceed the specified thickness by more than two gages.

(*d*) Hot-finished tubes shall not, at any place, exceed the specified thickness by more than three gages.

(*e*) The gaging tolerances in Paragraphs (*b*), (*c*), and (*d*) apply only to tubes as rolled or drawn and before swaging and expanding.

[1] A solution of 10 per cent hydrochloric acid (sp. gr. 1.19), 30 per cent sulfuric acid (sp. gr. 1.84), and 60 per cent water; or 25 per cent nitric acid (sp. gr. 1.42) and 75 per cent water, is recommended for the etch test.

(*f*) The length shall not be less but may be $\frac{3}{16}$ in. more than that specified.

17. Finished tubes shall be free from injurious defects and distortion, shall have smooth ends free from burrs and shall have a workmanlike finish. Finish.

MARKING

18. The name or brand of the manufacturer, the material from which it is made, whether steel or iron, and the pressure in pounds at which it was tested, shall be legibly stenciled on each tube. Marking.

INSPECTION AND REJECTION

19. (*a*) Unless otherwise specified, inspection and all tests, except check analyses, shall be made at the place of manufacture. When Inspection.

TABLE II.—STANDARD WEIGHTS OF SMALL SUPERHEATER TUBES.
SEAMLESS ONLY.

THICKNESS.		WEIGHT, LB. PER FT. OF LENGTH. Outside Diameter, in.											
B.w.g.	In.	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{13}{16}$	$\frac{7}{8}$	$\frac{15}{16}$	1	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{7}{16}$	$1\frac{1}{2}$	$1\frac{5}{8}$
14	0.083	0.480	0.535	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
13	0.095	0.537	0.601	0.664	0.727	.....	.....	.....	.....	.....	.....	.....	.....
12	0.109	.....	.....	0.746	0.818	0.891	.....	.....	.....	.....	.....	.....	.....
11	0.120	.....	.....	.....	0.887	0.967	1.047	1.127	.....	.....	.....	.....	.....
10	0.134	.....	.....	.....	.....	1.060	1.149	1.239	1.597	1.776	1.865	1.954	2.133
9	0.148	.....	.....	.....	.....	.....	1.247	1.346	1.741	1.939	2.038	2.138	2.334
8	0.165	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	2.352	.....

required, the manufacturer shall furnish the purchaser of each lot of tubes a statement as to the kind of material of which the tubes are made and that the tubes have been tested and have met all the requirements of these specifications.

(*b*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the tubes ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the tubes are being furnished in accordance with these specifications.

20. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 4 (*a*) shall be reported within five working days from the receipt of samples. Rejection.

(*b*) Tubes when inserted in the boiler shall stand expanding and beading without showing cracks or flaws, or opening at the weld. Superheater tubes when properly manipulated shall stand all forging, welding, and bending operations necessary for application without developing defects. Tubes which fail in any of the above operations will be rejected, and the manufacturer shall be notified.

Rehearing.

21. Samples tested in accordance with Section 4 (*a*) which represent rejected tubes, shall be preserved for two weeks from the date of test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

STANDARD SPECIFICATIONS
FOR
WELDED AND SEAMLESS STEEL PIPE[1]

Serial Designation: A 53 – 27

These specifications are issued under the fixed designation A 53; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ADOPTED, 1915; REVISED, 1918, 1921, 1924, 1927.

Scope.

1. These specifications cover "standard weight," "extra strong," and "double extra strong" welded and seamless steel pipe. Pipe ordered under these specifications is intended for coiling, bending, flanging and other special purposes. Butt-welded pipe is not intended for flanging. The purposes for which the pipe is intended should be stated in the order.[2] Where seamless pipe is ordered for coiling, bending or welding, the low-carbon grade should be specified.

MANUFACTURE

Process.

2. (*a*) The steel for welded pipe shall be soft weldable quality made by the bessemer or by the open-hearth process. The steel for seamless pipe shall be made by the open-hearth or electric-furnace process.

(*b*) Welded pipe 3 in. or under in nominal diameter may be butt-welded, unless otherwise specified. Welded pipe over 3 in. in nominal diameter shall be lap-welded.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

3. (*a*) Ladle tests of open-hearth steel shall conform to the following requirement as to chemical composition:

	LAP-WELDED	SEAMLESS
Phosphorus, per cent.....	not over 0.06	not over 0.045

Check Analyses.

(*b*) Analyses may be made by the purchaser from each lot of 500 lengths or less of finished pipe. The phosphorus content thus

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

[2] *Double Welding.*—Unless double welded pipe is specifically called for on the order, single welded pipe may be furnished. When double welded pipe is ordered the flattening test on crop ends specified in Section 9 shall be made with the weld on the side.

determined shall not exceed that specified in Paragraph (*a*) by more than 25 per cent. Drillings for analysis shall be taken from several points around each pipe.

PHYSICAL PROPERTIES AND TESTS

Tension Tests.

4. (*a*) The material shall conform to the following minimum requirements as to tensile properties:

	Welded		Seamless	
	Bessemer	Open-Hearth	Open-Hearth Low Carbon	Open-Hearth Medium Carbon
Tensile strength, lb. per sq. in....	50 000	45 000	48 000	62 000
Yield point, lb. per sq. in.....	30 000	25 000	26 500	35 000
Elongation in 8 in., per cent.....	18	20	.....	.....
Elongation in 2 in., per cent.....	.....	30	40	25

(*b*) The yield point shall be determined by the drop of the beam of the testing machine or other approved method.

Hydrostatic Tests.

5. Pipe shall be tested at the mill to the hydrostatic pressures specified in Table I. Welded pipe 2 in. and larger shall be jarred near one end while under test pressure.

Flattening Tests.

6. (*a*) For lap-welded pipe over 2 in. in nominal size, a section of pipe 4 to 6 in. in length shall be flattened between parallel plates until the distance between the plates is one-third the outside diameter of the pipe without developing cracks. In this test the weld shall be located 45 deg. from the line of direction of the applied force.

(*b*) For butt-welded pipe over 2 in. in nominal size, a section of pipe 4 to 6 in. in length shall be flattened between parallel plates until the distance between the plates is 60 per cent of the outside diameter of the pipe without developing cracks. In this test the weld shall be located 45 deg. from the line of direction of the applied force.

(*c*) For low-carbon seamless pipe over 2 in. in nominal size, a section of pipe not less than $2\frac{1}{2}$ in. in length shall be flattened between parallel plates until the distance between the plates is one-third the outside diameter of the pipe without developing cracks. In no case need the distance between the plates be less than five times the thickness of the pipe wall.

(*d*) For medium-carbon seamless pipe over 2 in. in nominal size, a section of pipe not less than $2\frac{1}{2}$ in. in length shall be flattened between parallel plates until the distance between the plates is one-half the outside diameter of the pipe without developing cracks. In no case need the distance between the plates be less than seven times the thickness of the pipe wall.

(*e*) The flattening test will not be required on double extra strong pipe.

Bend Tests.

7. For pipe 2 in. or under in nominal size, a sufficient length of pipe shall stand being bent cold through 90 deg. around a cylindrical mandrel the diameter of which is 12 times the nominal diameter of the pipe, without developing cracks at any portion and without opening the weld. When ordered for close coiling, the pipe shall stand being bent cold through 180 deg. around a mandrel the diameter of

TABLE I.—HYDROSTATIC PRESSURES FOR WELDED AND SEAMLESS STEEL PIPE
(Pressures Expressed in Pounds per Square Inch)

Size (Nominal Inside Diameter), in.	"Standard Weight" Pipe			"Extra Strong" Pipe			"Double Extra Strong" Pipe	
	Weight of Pipe per Linear Foot, Threaded and with Couplings, lb.	Butt-weld	Lap-weld and Seamless	Weight of Pipe per Linear Foot, Plain Ends, lb.	Butt-weld	Lap-weld and Seamless	Butt-weld	Lap-weld and Seamless
$\frac{1}{8}$	.....	700	....	.....	700	....	....	....
$\frac{1}{4}$	.....	700	....	.....	700	....	....	....
$\frac{3}{8}$	.....	700	....	.....	700	....	....	....
$\frac{1}{2}$	.....	700	....	.....	700	....	700	....
$\frac{3}{4}$	.....	700	....	.....	700	....	700	....
1	.....	700	....	.....	700	....	700	....
$1\frac{1}{4}$	.....	700	1000	.....	1500	2500	2200	....
$1\frac{1}{2}$	.....	700	1000	.....	1500	2500	2200	3000
2	.....	700	1000	.....	1500	2500	2200	3000
$2\frac{1}{2}$	.....	800	1000	.....	1500	2000	2200	3000
3	.....	800	1000	.....	1500	2000	2200	3000
$3\frac{1}{2}$	.....	...	1000	.....	....	2000	....	2500
4	.....	...	1000	.....	....	2000	....	2500
5	.....	...	1000	.....	....	1800	....	2000
6	.....	...	1000	.....	....	1800	....	2000
8	25.00	...	800	.....	....	....	....	2000
8	28.81	...	1000	43.39	....	1500	....	....
10	32.00	...	600	.....	....	....	....	....
10	35.00	...	700	.....	....	....	....	....
10	41.13	...	900	54.74	....	1000	....	....
12	45.00	...	600	.....	....	....	....	....
12	50.71	...	800	65.42	....	1000	....	....

For pipes over 12 in. in inside diameter, the test pressures should be calculated by the formula $P = \frac{2St}{D}$ in which P = pressure in pounds per square inch; S = fiber stress, 12,000 lb. per sq. in.; t = thickness of wall in inches; D = outside diameter in inches.

which is eight times the diameter of the pipe, without failure. The bend test will not be required on double extra strong pipe over $1\frac{1}{4}$ in. in diameter.

Test Specimens.

8. (*a*) Test specimens shall consist of sections cut from a pipe. They shall be smooth on the ends and free from burrs, except when made on crop ends taken from welded pipe.

(*b*) Tension test specimens shall be cut longitudinally from the pipe and not flattened. The sides of specimens shall be parallel between gage marks. Pipe may be pulled in full section if desired.

Where impractical to pull a test specimen in full thickness the A.S.T.M. standard one-half inch test specimen may be used.

(*c*) All specimens shall be tested at room temperature.

Number of Tests.

9. One of each of the tests specified in Sections 4, 6 and 7 shall be made on a length in each lot of 500 or less, of each size. Each length shall be subjected to the hydrostatic test. In the case of welded pipe ordered for "flanging," the crop ends cut from each length shall withstand the flattening test specified in Section 6 (*a*).

TABLE II.—STANDARD WEIGHTS AND DIMENSIONS OF WELDED AND SEAMLESS STEEL PIPE.

Size (Nominal Inside Diameter), in.	Outside Diameter, in.	"Standard Weight" Pipe			"Extra Strong" Pipe		"Double Extra Strong" Pipe	
		Number of Threads per Inch	Thickness, in.	Weight of Pipe per Linear Foot, Threaded and with Couplings, lb.	Thickness, in.	Weight of Pipe per Linear Foot, Plain Ends, lb.	Thickness, in.	Weight of Pipe per Linear Foot Plain Ends, lb.
$\frac{1}{8}$	0.405	27	0.068	0.25	0.095	0.31	.....	.....
$\frac{1}{4}$	0.540	18	0.088	0.43	0.119	0.54	.....	.....
$\frac{3}{8}$	0.675	18	0.091	0.57	0.126	0.74	.....	.....
$\frac{1}{2}$	0.840	14	0.109	0.85	0.147	1.09	0.294	1.71
$\frac{3}{4}$	1.050	14	0.113	1.13	0.154	1.47	0.308	2.44
1	1.315	$11\frac{1}{2}$	0.133	1.68	0.179	2.17	0.358	3.66
$1\frac{1}{4}$	1.660	$11\frac{1}{2}$	0.140	2.28	0.191	3.00	0.382	5.21
$1\frac{1}{2}$	1.900	$11\frac{1}{2}$	0.145	2.73	0.200	3.63	0.400	6.41
2	2.375	$11\frac{1}{2}$	0.154	3.68	0.218	5.02	0.436	9.03
$2\frac{1}{2}$	2.875	8	0.203	5.82	0.276	7.66	0.552	13.70
3	3.500	8	0.216	7.62	0.300	10.25	0.600	18.583
$3\frac{1}{2}$	4.000	8	0.226	9.20	0.318	12.51	0.636	22.85
4	4.500	8	0.237	10.89	0.337	14.98	0.674	27.54
5	5.563	8	0.258	14.81	0.375	20.78	0.750	38.55
6	6.625	8	0.280	19.19	0.432	28.57	0.864	53.16
*8	8.625	8	0.277	25.00	.....	.....	0.875	72.42
8	8.625	8	0.322	28.81	0.500	43.39	.....	.....
*10	10.750	8	0.279	32.00	.....	.....	.....	.....
*10	10.750	8	0.307	35.00	.....	.....	.....	.....
10	10.750	8	0.365	41.13	0.500	54.74	.....	.....
*12	12.750	8	0.330	45.00	.....	.....	.....	.....
12	12.750	8	0.375	50.71	0.500	65.42	.....	.....

* Unless specifically stated on the order the lighter weights will not be furnished. Weights given in the table are for pipes up to and including 12 in. in nominal inside diameter, with threaded ends and couplings; sizes larger than those shown in the table are measured by the outside diameter and will be furnished with plain ends unless otherwise specified; for such sizes it will be necessary to accept Manufacturers' weights or calculate the weights on the basis of one cubic inch of steel weighing 0.2833 lb.

Retests.

10. If the results of the physical tests of any lot do not conform to the requirements specified in Sections 4, 6 and 7, retests of two additional pipes shall be made, each of which shall conform to the requirements specified. In the case of flattening tests on the crop ends of each length of welded pipe, if any section fails, other pieces from the length may be cut until satisfactory tests are obtained, otherwise the length shall be rejected.

STANDARD WEIGHTS

11. (*a*) The standard weights for pipe of various inside diameters are given in Table II. **Standard Weights.**

(*b*) Nipples shall be cut from pipe of the same weight and quality as described in these specifications.

12. The weight of the pipe shall not vary more than 5 per cent for standard weight and extra strong pipe nor more than 10 per cent for double extra strong pipe from that specified in Table II. **Permissible Variations.**

13. Unless otherwise specified, pipe shall be furnished as to lengths in accordance with the following regular practice: **Lengths.**

(*a*) Standard weight pipe shall be in random lengths of 16 to 22 ft., but not more than 5 per cent of the total number of lengths may be "jointers," which are two pieces coupled together. When ordered with plain ends, 5 per cent may be in lengths of 12 to 16 ft.

(*b*) Extra strong and double extra strong pipe shall be in random lengths of 12 to 22 ft. Five per cent may be in lengths of 6 to 12 ft.

WORKMANSHIP AND FINISH

14. For pipe $1\frac{1}{2}$ in. or under in nominal size, the outside diameter at any point shall not vary more than $\frac{1}{64}$ in. over nor more than $\frac{1}{32}$ in. under the standard outside diameter. For pipe 2 in. or over in nominal size, the outside diameter shall not vary more than 1 per cent over or under the standard outside diameter. The wall thickness shall not be more than 12.5 per cent under the nominal wall thickness at any point. **Workmanship.**

15. Unless otherwise specified, pipe shall conform to the following regular practice: **Ends.**

(*a*) Each end of standard weight welded pipe shall be threaded.

(*b*) Extra strong welded pipe and standard weight and extra strong seamless pipe and all double extra strong pipe shall be furnished with plain ends.

(*c*) All threads shall be in accordance with the American Standard[1] and cut so as to make a tight joint when the pipe is tested at the mill to the specified internal hydrostatic pressure. The variation from the standard, when tested with the standard working gage, shall not exceed a maximum of one and one-half turns either way. **Threads.**

(*d*) Each length of threaded pipe shall be provided with one coupling, having clean-cut threads of such a pitch diameter as to make a tight joint. Couplings may be made of wrought iron or steel. **Couplings.**

[1] A complete description of the American Standard Pipe Thread is contained in the Pipe Thread Standard prepared under the sponsorship of the American Gas Association and the American Society of Mechanical Engineers and approved as American Standard by the American Engineering Standards Committee.

Finish. 16. The finished pipe shall be reasonably straight and free from injurious defects. All burrs at the ends of the pipe shall be removed.

INSPECTION AND REJECTION

Inspection. 17. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the pipe ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the pipe are being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection. 18. Each length of pipe which develops injurious defects in shop working or application will be rejected, and the manufacturer shall be notified.

STANDARD SPECIFICATIONS
FOR
CARBON TOOL STEEL[1]

Serial Designation: A 71 – 26

These specifications are issued under the fixed designation A 71; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1917; ADOPTED IN AMENDED FORM, 1926.

Scope.

1. (*a*) These specifications cover carbon tool steels, the composition of which shall be as agreed upon by the purchaser and the vendor, with the permissible variations specified in Section 4.

(*b*) These steels are suitable for lathe and planer tools, drills and milling cutters, dies and other miscellaneous purposes, etc.

MANUFACTURE

Process.

2. The steel shall be made either by the crucible or electric-furnace process.

Annealing.

3. The steel shall be furnished unannealed unless otherwise specified.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

4. The composition of the tool steels shall be as agreed upon by the purchaser and the vendor with the following permissible variations in composition:

		Permissible Variation, per cent	
		Over	Under
Carbon		0.05	0.05
Manganese	when under 1.00	0.10	0.10
	when over 1.00	0.20	0.20
Phosphorus		0.005	....
Sulfur		0.005	....
Silicon		0.15	0.15

Other elements as agreed.

Method of Sampling.

5. (*a*) Milled samples for analysis shall be taken from the sample bar to represent the full cross-section, or drillings shall be taken by drilling a bar midway between the center and the surface, parallel to the axis of the bar. In either case the decarburized material shall be rejected.

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

(*b*) In general, the minimum depth to which the surface shall be removed before a sample is taken shall be in accordance with the following requirements:

THICKNESS OR DIAMETER, IN.	MATERIAL REMOVED, IN.
1 or under	$\frac{1}{32}$
Over 1 to $2\frac{1}{2}$, inclusive	$\frac{1}{16}$
Over $2\frac{1}{2}$ to 4, inclusive	$\frac{1}{8}$
Larger sizes	As agreed

(*c*) In the case of drill rod and other material of similar finish where freedom from decarburization is specified, samples shall be taken from the surface in addition to the methods described in Pargraph (*a*).

Standard Methods of Analysis.

6. In case of dispute, the chemical analysis shall be made in accordance with the Standard Methods of Chemical Analysis of Plain Carbon Steel (Serial Designation: A 33) of the American Society for Testing Materials.[1]

MANUFACTURING TOLERANCES IN DIMENSIONS

7. Variations in the cross-sectional dimensions of the material shall not exceed the following amounts:

FORGED AND ROLLED MATERIAL

	PERMISSIBLE VARIATION, IN.	
	OVER	UNDER
$\frac{1}{2}$ in. or under	0.010 ($\frac{1}{100}$)	0.010 ($\frac{1}{100}$)
Over $\frac{1}{2}$ in. to 1 in., inclusive	0.015 ($\frac{1}{64}$)	0.015 ($\frac{1}{64}$)
Over 1 in. to $1\frac{1}{2}$ in., inclusive	0.031 ($\frac{1}{32}$)	0.031 ($\frac{1}{32}$)
Over $1\frac{1}{2}$ in. to 2 in., inclusive	0.046 ($\frac{3}{64}$)	0.031 ($\frac{1}{32}$)
Over 2 in. to 4 in., inclusive	0.125 ($\frac{1}{8}$)	0.031 ($\frac{1}{32}$)
Over 4 in. to 6 in., inclusive	0.156 ($\frac{5}{32}$)	0.031 ($\frac{1}{32}$)
Over 6 in. to 8 in., inclusive	0.188 ($\frac{3}{16}$)	0.063 ($\frac{1}{16}$)
Over 8 in	0.250 ($\frac{1}{4}$)	0.063 ($\frac{1}{16}$)
FINISHED MATERIAL (DRILL ROD)		
$\frac{7}{16}$ in. and under	0.0005	0.0005
Over $\frac{7}{16}$ in	0.001	0.001

FINISH

Finish.

8. (*a*) The material shall be free from injurious defects and shall have a workmanlike finish.

(*b*) All drill rods shall be coated with a rust preventive.

MARKING

Marking.

9. (*a*) Identification marks shall be stamped on the material as agreed by the purchaser and the vendor. All identification marks shall be about $\frac{1}{4}$ in. in height when the size permits.

[1] See p. 276.

(*b*) In lieu of marking as specified in Paragraph (*a*), the ends of bars and rods may be painted as agreed by the purchaser and the vendor.

Bundling Small Sizes.

10. All rods and bars of which the largest cross-sectional dimension is $\frac{3}{8}$ in. or less shall be boxed or bundled, each box or bundle to contain bars or rods of the same size, shape and class of material. A metal tag shall be securely attached to the wrapping wire or box. Rods and bars of cross-sectional dimensions exceeding $\frac{3}{8}$ in. and not exceeding $1\frac{1}{2}$ in., where convenient to purchaser and vendor, may be bundled and marked as specified above. Bundles shall be of suitable size to permit easy handling and shall be securely fastened.

INSPECTION AND REJECTION

Inspection.

11. The vendor shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications.

Comparison with Selective Sample.

12. The steel shall correspond in quality and characteristics to the samples submitted under the specifications and approved by the purchaser.

Rejection.

13. Material which does not conform to the chemical composition and specified dimensions, or which at any time shows injurious defects inherent in the steel, will be rejected and the vendor shall be notified.

APPENDIX

RECOMMENDED PRACTICE FOR THE HEAT TREATMENT OF PLAIN CARBON TOOL STEEL[1]

General.—This recommended practice covers the process to be followed in the heat treating of plain carbon tool steel.

PART I.—NORMALIZING OF TOOL STEEL BEFORE HARDENING

Operations:

Heating.
Cooling.

Heating: Place steel in furnace so as to expose maximum surface area. Heat uniformly to a temperature above the upper critical point indicated in Table I, and hold at this temperature for sufficient time to obtain complete penetration of heat and for complete refinement of grain.

Cooling: Remove from furnace and cool freely in air.

[1] This is a Recommended Practice approved by the Recommended Practice Committee and Board of Directors of the American Society for Steel Treating and is published by permission of that Society.

TABLE I.—NORMALIZING TEMPERATURE AND CARBON RANGE.

CARBON RANGE, PER CENT	NORMALIZING TEMPERATURE DEG. FAHR.	DEG. CENT.
0.65 – 0.80	1475 – 1525	800 – 830
0.80 – 0.95	1475 – 1500	800 – 815
0.95 – 1.10	1500 – 1575	815 – 860
1.10 – 1.25	1575 – 1650	860 – 900

CROSS-SECTIONS, WEIGHT AND TIME

THICKNESS OF LARGEST SECTION OF UNIT	WEIGHT OF UNIT, LB. (APPROXIMATE)	TIME OF HEATING, HR. (APPROX.)	TIME OF HOLDING, HR. (APPROX.)
Up to and including 1 in.	Up to 100	$\frac{3}{4}$	$\frac{1}{2}$
Over 1 in. and including 2 in.	Over 100 and including 300	$1\frac{1}{4}$	$\frac{1}{2}$
Over 2 in. and including 3 in.	Over 300 and including 500	$1\frac{3}{4}$	$\frac{3}{4}$
Over 3 in. and including 4 in.	Over 500 and including 1000	$2\frac{1}{4}$	1
Over 4 in. and including 5 in.	Over 1000 and including 1500	$2\frac{3}{4}$	1
Over 5 in. and including 8 in.	Over 1500 and including 2000	$3\frac{1}{2}$	$1\frac{1}{2}$

PART II.—HEAT TREATING OF PLAIN CARBON TOOL STEEL

Operations:

Heating for quenching.
Quenching.
Tempering.

Heating: Heat the steel uniformly to the temperature indicated in Table II

Quenching: Quench from this temperature in water, but do not cool below temperature of boiling water (212° F. (100° C.)).

TABLE II.—HEAT TREATING.

CARBON RANGE, PER CENT	HARDENING TEMPERATURE, DEG. FAHR.	DEG. CENT.	QUENCHING MEDIUM AND ITS TEMPERATURE
0.65 – 0.80	1550 – 1450	843 – 788	Water at 70° F. (21° C.)
0.81 – 0.95	1460 – 1410	793 – 766	Water at 70° F. (21° C.)
0.96 – 1.10	1430 – 1390	777 – 754	Water at 70° F. (21° C.)
1.11 – 1.25	1420 – 1380	771 – 749	Water at 70° F. (21° C.)

Tempering: Reheat immediately in oil, salt ($NaNO_3$) or furnace for the time and at the temperature specified in Table III and cool.

TABLE III.—TEMPERING TOOL STEEL.

RESULTS DESIRED	TEMPERING MEDIUM	TEMPERATURE, DEG. FAHR.	DEG. CENT.
Relieving Strains	Oil	350 – 375	177 – 191
Relieving Strains, and Reducing Brittleness	Oil	400 – 500	204 – 260
To Relieve Strains and to Toughen	Oil	500 – 600	260 – 316

NOTES ABOUT THE PROCESS

1. *General.*—The recommended practice for the heat treatment of tool steel applies to the highest quality performance of tools for general purposes only. For specific applications where special structural requirements seem to be necessary, deviation from the recommended practice must be left to the judgment of the individual heat treater or metallurgist.

2. *Normalizing.*—A normalizing treatment for all tool steels is recommended to obtain a uniform and refined grain structure, which enables the operator to predict the behavior and performance of the tool steel during heating and quenching for hardening.

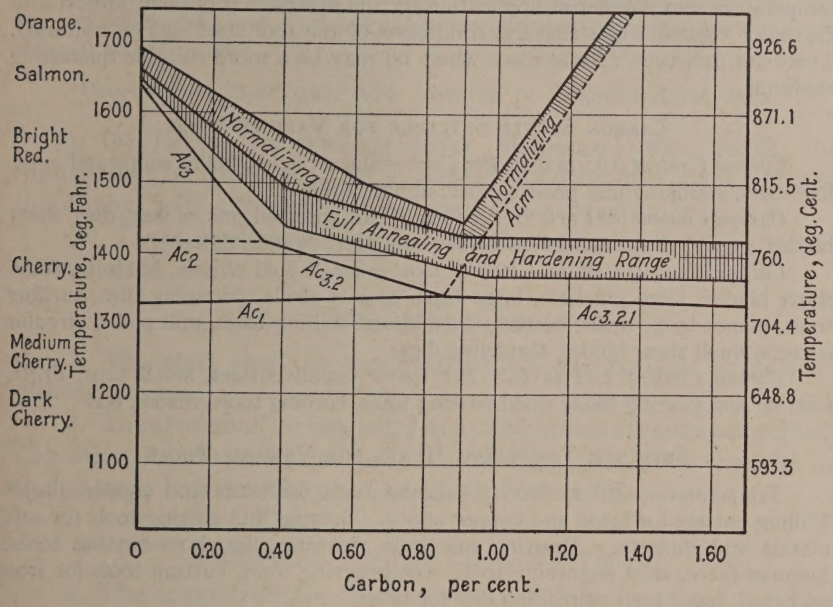


FIG. 1.—Critical Range Diagram for Iron-Carbon Alloys, Showing Normalizing, Annealing and Hardening Ranges.

The variation in temperature for the different carbon ranges becomes evident upon a careful examination of the critical range diagram. A temperature very much in excess of that required to produce solid solution (austenite) is conducive to austenitic grain growth and intergranular weakness.

A low normalizing temperature for high-carbon steels (1.25 to 1.50 per cent carbon) which fails to break up the massive cementite results in a brittle structure, since the rate of diffusion of the excess cementite depends upon the temperature. The solubility of carbide in iron being greater, or increasing as the temperature rises, the rate of this solubility is equivalent to the slope of the Acm. line in the diagram.

The higher normalizing temperatures given in Table I apply to the lower carbon ranges and the lower temperature to the higher carbon ranges for steel of the hypo-eutectoid composition, or, in other words, "the normalizing temper-

atures for hypo-eutectoid steels varies indirectly as the carbon percentage rises or falls, and the normalizing temperature of hyper-eutectoid steels varies directly with the percentage of carbon."

3. *Heating for Quenching.*—(*a*) The wide range of temperature in the 0.65 to 0.80 per cent carbon steel is needed, as a number of tools such as shear blades, arbors, mandrels, and others are all around the low point, and, because of mass and forms, require somewhat higher temperatures for quenching.

(*b*) The quenching temperatures given are at the lowest temperature range consistent with highest quality tools; deviations from it are not recommended, but may be practical for diverse reasons.

Quenching.—Water is the universal quenching medium, and by varying its temperature and manner of application for the abstraction of heat, almost any degree of variation of structural conditions of the tool steel can be obtained. There are, however, special cases where oil may be a more suitable quenching medium.

CARBON STEELS SUITABLE FOR VARIOUS USES

Carbon Content 0.65 to 0.85 Per Cent.—Shear blades, boiler snaps and cups, hammers, stamping and pressing dies, mining drills.

Carbon Content 0.81 to 0.95 Per Cent.—Hot and cold sets, chisels, dies, shear blades, mining drills, smiths' tools, set hammers, swages, flatteners.

Carbon Content 0.96 to 1.10 Per Cent.—Small cold chisels, hot sets, small shear blades, large pinchers, large taps, granite drills, trimming dies, turning tools, planer tools, drills, cutters, slotting and milling tools, mill picks, circular cutters, small shear blades, threading dies.

Carbon Content 1.11 to 1.25 Per Cent.—Small cutters, small taps, drills, slotting and planing tools, wood-cutting tools, turning tools, razors, etc.

SUITABLE TEMPERING HEATS FOR VARIOUS TOOLS

Temperatures, 350 to 390° F.—Lathe tools for brass and copper alloys. Milling cutters for brass and copper alloys. Scraper and cutting tools for soft metals and micarta. Drawing mandrels, drawing dies, bone-cutting tools, hammer-faces, steel engraving tools, wood-carving tools, cutting tools for iron and steel, hand tools, threading dies for brass.

Temperature, 400 to 500° F.—Hand taps and dies, hand reamers, drills, bits, cutting dies, penknives, milling cutters, chasers, inserted sawteeth, press dies for sheet steel, rock drills, taps and dies, wire-drawing dies, dental and surgical instruments, twist drills.

Temperature, 500 to 600° F.—Bending and forming dies, shear blades, chuck jaws, forging dies, drifts, gages, press-dies, flat drills, reamers, chisels and tools for wood-cutting, hammers and drop dies, axes, lathe tools for copper augers, cold chisels, coppersmith tools, grinders, screw drivers, molding and planing tools, hacksaws, needles, butcher knives and saws.

STANDARD SPECIFICATIONS
FOR
HIGH-SPEED TOOL STEEL[1]

Serial Designation: A 92 - 26

These specifications are issued under the fixed designation A 92; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

PROPOSED AS TENTATIVE, 1924; ADOPTED IN AMENDED FORM, 1926.

Scope.

1. (*a*) These specifications cover high-speed tool steels, the composition of which shall be as agreed upon by the purchaser and the vendor, with the permissible variations specified in Section 4.

(*b*) These steels are suitable for lathe and planer tools, milling cutters, drills, etc.

MANUFACTURE

Process.

2. The steel shall be made either by the crucible or electric-furnace process.

Annealing and Hardness.

3. The steel shall be furnished annealed unless otherwise specified. The microstructure, Brinell hardness and fracture tests shall be as agreed upon between the purchaser and the vendor.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

4. The composition of the tool steels shall be as agreed upon by the purchaser and the vendor with the following permissible variations in composition:

	Permissible Variations, per cent	
	Over	Under
Carbon	0.05	0.05
Manganese	0.15	0.15
Phosphorus	0.01	....
Sulfur	0.01	....
Silicon	0.15	0.15
Chromium	0.50	0.50
Vanadium	0.25	0.25
Tungsten	0.75	0.75
Cobalt	0.50	0.50
Other elements as agreed.		

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

Method of Sampling.

5. (*a*) Milled samples for analysis shall be taken from the sample bar to represent the full cross-section, or drillings shall be taken by drilling a bar midway between the center and the surface, parallel to the axis of the bar. In either case the decarburized material shall be rejected.

(*b*) In general, the minimum depth to which the surface shall be removed before a sample is taken shall be in accordance with the following requirements:

THICKNESS OR DIAMETER, IN.	MATERIAL REMOVED, IN.
1 or under	$\frac{1}{32}$
Over 1 to $2\frac{1}{2}$, inclusive	$\frac{1}{16}$
Over $2\frac{1}{2}$ to 4, inclusive	$\frac{1}{8}$
Larger sizes	As agreed

(*c*) In the case of drill rod and other material of similar finish where freedom from decarburization is specified, samples shall be taken from the surface in addition to the methods described in Paragraph (*a*).

Standard Methods of Analysis.

6. In case of dispute, the chemical analysis shall be made in accordance with the Standard Methods of Chemical Analysis of Alloy Steels (Serial Designation: A 55) of the American Society for Testing Materials.[1]

MANUFACTURING TOLERANCES IN DIMENSIONS

Manufacturing Tolerances in Dimensions.

7. Variations in cross-sectional dimensions of the material shall not exceed the following amounts:

FORGED AND ROLLED MATERIAL

	PERMISSIBLE VARIATIONS, IN.	
	OVER	UNDER
$\frac{1}{2}$ in. or under	0.010 ($\frac{1}{100}$)	0.010 ($\frac{1}{100}$)
Over $\frac{1}{2}$ in. to 1 in., inclusive	0.015 ($\frac{1}{64}$)	0.015 ($\frac{1}{64}$)
Over 1 in. to $1\frac{1}{2}$ in., inclusive	0.031 ($\frac{1}{32}$)	0.031 ($\frac{1}{32}$)
Over $1\frac{1}{2}$ in. to 2 in., inclusive	0.046 ($\frac{3}{64}$)	0.031 ($\frac{1}{32}$)
Over 2 in. to 4 in., inclusive	0.125 ($\frac{1}{8}$)	0.031 ($\frac{1}{32}$)
Over 4 in. to 6 in., inclusive	0.156 ($\frac{5}{32}$)	0.031 ($\frac{1}{32}$)
Over 6 in. to 8 in., inclusive	0.188 ($\frac{3}{16}$)	0.063 ($\frac{1}{16}$)
Over 8 in	0.250 ($\frac{1}{4}$)	0.063 ($\frac{1}{16}$)
FINISHED MATERIAL (DRILL ROD)		
$\frac{7}{16}$ in. and under	0.0005	0.0005
Over $\frac{7}{16}$ in	0.001	0.001

FINISH

Finish.

8. (*a*) The material shall be free from injurious defects and shall have a workmanlike finish.

(*b*) All drill rods shall be coated with a rust preventive.

[1] See p. 300.

MARKING

9. (*a*) Identification marks shall be stamped on the material as agreed by the purchaser and the vendor. All identification marks shall be about $\frac{1}{4}$ in. in height when the size permits. **Marking.**

(*b*) In lieu of marking as specified in Paragraph (*a*), the ends of the bars and rods may be painted as agreed by the purchaser and the vendor.

10. All rods and bars of which the largest cross-sectional dimension is $\frac{3}{8}$ in. or less shall be boxed or bundled, each box or bundle to contain bars or rods of the same size, shape and class of material. A metal tag shall be securely attached to the wrapping wire or box. Rods and bars of cross-sectional dimensions exceeding $\frac{3}{8}$ in. and not exceeding $1\frac{1}{2}$ in., where convenient to vendor and purchaser, may be bundled and marked as specified above. Bundles shall be of suitable size to permit easy handling and shall be securely fastened. **Bundling Small Sizes.**

INSPECTION AND REJECTION

11. The vendor shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. **Inspection.**

12. The steel shall correspond in quality and characteristics to the samples submitted under the specifications and approved by the purchaser. **Comparison with Selective Sample.**

13. Material which does not conform to the chemical composition and specified dimensions, or which at any time shows injurious defects inherent in the steel, will be rejected and the vendor shall be notified. **Rejection.**

APPENDIX

RECOMMENDED PRACTICE FOR THE HEAT TREATMENT OF 18-PER-CENT TUNGSTEN HIGH-SPEED STEEL[1]

General.—This recommended practice covers the process to be followed in the heat treating of high-speed steel.

Operations:

1. Heating for annealing.
2. Cooling.
3. Heating for hardening—(*a*) Preheating—(*b*) Heating for quenching.
4. Quenching.
5. Tempering for secondary hardness.

[1] This is a Recommended Practice approved by the Recommended Practice Committee and Board of Directors of the American Society for Steel Treating and is published by permission of that Society.

1. *Heating for Annealing.*—Heat slowly and uniformly to a temperature of 1600° F. (871° C.) and hold for complete adjustment and for complete uniformity of grain.

2. *Cooling.*—Cool in furnace, infusorial earth, mica, lime or any medium, that will permit of uniform slow cooling.

3. *Heating for Hardening.*—(*a*) Preheating—Heat slowly and uniformly to 1500° F. (816° C.) in a furnace of sufficient size.

(*b*) Heating for Quenching—Transfer preheated steel to a high-temperature furnace that is maintained at a temperature of 2250 to 2400° F. (1232 to 1315° C.), depending on the type of tools being hardened.

In order to obtain the most satisfactory "red hardness" conditions, the steel should be brought rapidly to the higher temperature; but in many cases the character of the cutting edges of certain form tools, such as milling cutters, threading tools, etc., makes it inadvisable to use the higher temperatures owing to destruction of the delicate edges through blistering, pitting, etc. It is, therefore, usual to use the higher temperatures for tools such as rough lathe tools, while the finer class of tools is hardened at the lower temperatures.

High-speed steel tools should not be held at the high heat longer than necessary, since holding at the high hardening temperatures causes excessive grain growth, with subsequent brittleness of the hardened tools.

Tools that cannot be ground after hardening are often heated in a barium chloride, or some such suitable salt bath.

4. *Quenching.*—Quench the steel in oil, or air, from the hardening temperature. It is advisable to maintain the oil quenching bath at a temperature of 150 to 200° F. (65 to 93° C.) to eliminate possibility of breakage with intricately shaped tools.

5. *Tempering for Secondary Hardness.*—Reheat uniformly in an open furnace, lead bath, or preferably in a sodium nitrate ($NaNO_3$) bath, or any other suitable salt bath, to a temperature of 1050 to 1150° F. (565 to 631° C.) for a sufficient length of time, and cool in air.

NOTES ABOUT THE PROCESS

Cooling from Annealing.—Cooling in air should not be permitted, since air cooling from the annealing temperature is likely to result in partial hardening of the tool.

Heating for Hardening.—It is the customary practice to always preheat for hardening in an open furnace, since preheating in a salt bath causes the salt to adhere to the tool, and the subsequent high temperature treatment causes unusual corroding from the adhering salt. Even preheating in lead is objectionable from small quantities of adhering lead. There is not much advantage to be gained in using a molten bath for the preheating, since the preheating temperature may vary over the comparatively wide range of 1400 to 1600° F (760 to 870° C.) and an open furnace is invariably used in practice.

Quenching from Tempering Temperatures.—Quenching from the tempering temperatures is not advisable with high-speed steel.

STANDARD SPECIFICATIONS
FOR
ALLOY-STEEL BOLTING MATERIAL FOR HIGH-TEMPERATURE SERVICE[1]

Serial Designation: A 96 – 27

These specifications are issued under the fixed designation A 96; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1925; ADOPTED IN AMENDED FORM, 1926; REVISED, 1927.

Scope.

1. (*a*) These specifications cover alloy-steel bolting material for valves, flanges and fittings for high-temperature service (Note 1). The term "bolting material" as used in these specifications covers rolled, forged or cold-drawn bars, and bolts, screws and studs.

(*b*) Three classes of material are covered, A, B and C, classified in accordance with their physical properties as specified in Section 10.

(*c*) Nickel, chrome-nickel, chrome-vanadium, chrome-manganese or any other types of alloy steel approved by the purchaser may be submitted under these specifications.

(*d*) Carbon-steel nuts and washers for use with this bolting material are covered in Section 16.

Basis of Purchase.

2. When agreed upon between the manufacturer and the purchaser, Brinell hardness tests may be made to determine the acceptance of bolting material in lieu of the tension tests herein specified; but shall not be used as a basis for rejection without confirming tension tests being made.

Certification of Test for Bolts, Screws and Studs.

3. Unless otherwise specified on the order, a certification that bolts, screws and studs for valves and other fittings intended for stock and other purposes requiring assembly in the manufacturer's plant conform to the requirements of these specifications, shall be accepted in lieu of the tests herein specified.

MANUFACTURE

Process.

4. The steel shall be made by one or more of the following processes: open-hearth, electric-furnace or crucible.

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

Discard.

5. A sufficient discard shall be made from each ingot to secure freedom from injurious piping and undue segregation.

Heat Treatment.

6. (*a*) Heat treatment shall consist of quenching and tempering.

(*b*) Immediately after rolling or forging, the bolting material shall be allowed to cool to a temperature below the critical range under suitable conditions to prevent injury by too rapid cooling. For quenching and tempering, the material shall then be uniformly reheated to the proper temperature to refine the grain (a group thus reheated being known as a "quenching charge") and quenched in some medium under substantially uniform conditions for each quenching charge. The material shall then be uniformly reheated to the proper temperature for tempering or "drawing back" (a group thus reheated being known as a "tempering charge") and allowed to cool uniformly.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

7. (*a*) The steel shall conform to the following requirements as to chemical composition:

Phosphorus, per cent	not over 0.045
Sulfur, per cent	not over 0.05

(*b*) The composition of the steel furnished under these specifications, other than phosphorus and sulfur, shall be agreed upon by the manufacturer and the purchaser.

NOTE.—It is recommended that the carbon content shall not be less than 0.20 nor more than 0.45 per cent, and that the carbon ranges shall be 0.10 per cent of carbon.

Ladle Analyses.

8. An analysis of each melt of steel shall be made by the steel manufacturer to determine the percentages of the elements present. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 7.

Check Analyses.

9. Analyses may be made by the purchaser from samples representing the bolting material. The chemical composition thus determined shall conform to the requirements specified in Section 7.

PHYSICAL PROPERTIES AND TESTS

Tension Tests.

10. (*a*) The bolting material, after final heat treatment, shall conform to the following requirements as to minimum tensile properties:

	CLASS A	CLASS B	CLASS C
Tensile strength, lb. per sq. in..	95 000	105 000	125 000
Yield point, lb. per sq. in.....	70 000	80 000	105 000
Elongation in 2 in., per cent....	20	20	16
Reduction of area, per cent.....	50	50	50

(*b*) The yield point shall be determined by the drop of the beam of the testing machine or by the use of dividers.

Brinell Hardness Tests.

11. (*a*) When Brinell hardness tests are made, the bolting material, after final heat treatment, shall conform to the following requirements:

	BRINELL HARDNESS NUMBER
Class A	190 – 250
Class B	210 – 270
Class C	260 – 320

(*b*) The Brinell hardness test shall be made in accordance with the Standard Methods of Brinell Hardness Testing of Metallic Materials (Serial Designation: E 10) of the American Society for Testing Materials.[1]

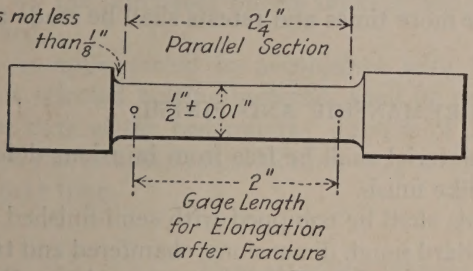

Radius not less than 1/8"
2 1/4"
Parallel Section
1/2" ± 0.01"
2"
Gage Length for Elongation after Fracture
Note:-The Gage Length, Parallel Section, and Fillets shall be as Shown, but the Ends may be of any Shape to fit the Holders of the Testing Machine in such a Way that the Load shall be axial.

FIG. 1.

Tension Test Specimens.

12. (*a*) The tension test specimens taken from the bolting material shall conform to the dimensions shown in Fig. 1, except as specified in Paragraph (*b*). The ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial.

(*b*) In the case of small sections which will not permit of taking the standard tension test specimen specified in Paragraph (*a*), the tension test specimen shall be as large as feasible and its dimensions shall be proportional to those shown in Fig. 1. The gage length for measuring elongation shall be four times the diameter of the specimen.[2]

[1] See p. 804.

[2] These requirements are in accordance with the provisions of Section 8 of the Tentative Methods of Tension Testing of Metallic Materials (Serial Designation: E 8 – 27 T), *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I (1927); also 1927 Book of A.S.T.M. Tentative Standards.

Number of Tests.

13. (*a*) Except as specified in Paragraph (*b*), one tension test shall be made for each lot of 100 pieces or less of bolting material from each tempering charge. If more than one quenching charge is represented in a tempering charge, one tension test shall be made from each lot of 100 pieces or less from each quenching charge. If more than one melt is represented in a quenching charge, one tension test shall be made from each lot of 100 pieces or less from each melt.

(*b*) Unless required on the order, tension tests shall not be made on an order of less than 100 bolts, screws or studs; in which case acceptance shall be based upon the provisions in Sections 2 or 3.

(*c*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*d*) If the percentage of elongation of any test specimen is less than that specified in Section 10 (*a*) and any part of the fracture is outside of the middle three-fourths of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

Retests.

14. If the results of the physical tests of any lot of bolting material do not conform to the requirements specified, the manufacturer may re-treat such lot one or more times and retests shall be made as specified in Section 13 (*a*).

WORKMANSHIP AND FINISH

Finish.

15. The bolting material shall be free from injurious defects and shall have a workmanlike finish.

Nuts and Washers.

16. Bolts and studs shall be equipped with semi-finished carbon-steel nuts of U. S. Standard rough dimensions, chamfered and trimmed. If washers are used under nuts they shall be of forged or rolled steel. All nuts and washers shall be free from injurious defects and shall have a workmanlike finish. Nuts shall conform to the chemical requirements for phosphorus and sulfur as follows:

	Class A	Class B
Phosphorus, per cent, not over	0.045	0.05
Sulfur, per cent, not over	0.05	0.15

Threads.

17. U. S. Standard threads shall be used, except that no stud shall have less than eight threads per inch.

MARKING

Identification Marks.

18. Identification marks to be stamped on bolting material shall be agreed upon between the manufacturer and the purchaser.

INSPECTION AND REJECTION.

Inspection.

19. (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the bolting material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the bolting material is being furnished in accordance with these specifications. Tests and inspection at the place of manufacture shall be made prior to shipment.

(*b*) The purchaser may make the tests to govern the acceptance or rejection of the bolting material in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

(*c*) Tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection.

20. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 19 (*b*) shall be reported within twelve working days from the receipt of samples.

(*b*) Bolting material which shows injurious defects while being finished by the purchaser will be rejected and the manufacturer shall be notified.

Rehearing.

21. Samples tested in accordance with Section 19 (*b*), which represent rejected bolting material, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the test, the manufacturer may make claim for a rehearing within that time.

EXPLANATORY NOTES

NOTE 1.—This contemplates temperatures up to 750° F. (400° C.); or at the discretion of the designing engineer higher temperatures with appropriate pressures may be used. Reference may be made to the dimensional standards for pressures and temperatures formulated by the Sectional Committee on Standardization of Pipe Flanges and Fittings, under the sponsorship of the Heating and Piping Contractors National Association, Manufacturers Standardization Society of the Valve and Fittings Industry and the American Society of Mechanical Engineers, and organized under the procedure of the American Engineering Standards Committee.

STANDARD SPECIFICATIONS
FOR
ZINC-COATED (GALVANIZED) SHEETS[1]

Serial Designation: A 93 – 27

These specifications are issued under the fixed designation A 93; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1924; ADOPTED IN AMENDED FORM, 1927.

Scope.

1. These specifications cover sheets of bessemer steel, open-hearth steel, and open-hearth iron, with five classes of zinc coatings, applied by the hot-dip process, as follows:

Class A.—Extra heavily coated sheets that are not intended to be formed other than by corrugating.

Class B.—Heavily coated sheets that are not intended to be formed other than by corrugating and curving to large radii.

Class C.—Moderately heavily coated sheets for moderate bending.

Class D.—Ordinary coated sheets for general utility. These coatings approximate those of Class C except in medium gages in which coatings of Class D are appreciably lighter. Class D represents material generally available in warehouse stocks, which is not intended for use where relatively long life, represented by Classes A, B and C, or severe forming, represented by Class E, is required.

Class E.—Sheets having lighter, more tightly adherent coatings to reduce liability of flaking in severe forming. The sheet maker should be made acquainted with the requirements of fabrication.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

2. No detailed requirements for the chemical composition of the base metal are specified, except when base metal containing copper is ordered, in which case it shall conform to the following requirements:

Copper, minimum	ladle analysis	0.20 per cent
	check analysis	0.18 "

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-5 on Corrosion of Iron and Steel.

3. An analysis of copper-bearing sheets may be made by the purchaser from the test specimens specified in Section 6. The copper content thus determined shall conform to the requirements specified in Section 2. Check Analysis.

PHYSICAL PROPERTIES AND TESTS

4. (*a*) The weight of the zinc coating shall conform to the requirements specified in Tables I and II. The weight of coating is the total coating, expressed in ounces, on both sides of a sheet 1 ft. square. Weight of Coating.

TABLE I.—DESIRED OR ORDERED WEIGHT OF COATINGS, OZ. PER SQ. FT.

GALVANIZED SHEET GAGE	CLASS A	CLASS B	CLASS C	CLASS D	CLASS E
No. 8.....	2.75	2.50	2.00	No	No
No. 9.....	2.75	2.50	2.00	specified	specified
No. 10.....	2.75	2.50	2.00	coatings,	coatings,
No. 11.....	2.75	2.50	2.00	see	see
No. 12.....	2.75	2.50	2.00	Section 1	Section 1
No. 13.....	2.75	2.50	2.00		
No. 14.....	2.75	2.50	2.00		
No. 16.....	2.75	2.50	2.00		
No. 18.....	2.75	2.50	1.75		
No. 20.....	2.75	2.50	1.75		
No. 22.....	2.75	2.50	1.75		
No. 24.....	....	2.50	1.50		
No. 26.....	....	2.25	1.25		
No. 27.....	....	2.00	1.25		
No. 28.....	....	1.75	1.25		
No. 29.....	....	1.50	1.25		
No. 30.....	....	1.25	1.25		

(*b*) The weight test is to be preferred and shall consist of a 10-sheet lot of a light gage or a 5-sheet lot of No. 16 gage or heavier. The test lots shall be weighed after pickling, washing and drying, and again after coating, and the weight of coating calculated from the difference on the basis of the ordered size. The scale used shall be sensitive to $\frac{1}{2}$ lb. The average of weight tests shall be determined from not less than ten successive weight tests that have met the requirements of the specification as provided in Section 7 (*a*).

(*c*) The triple spot test shall consist of the average of determinations from the three specimens cut from the test sheet as provided in Sections 6 and 7 (*b*). The average of triple spot tests shall be determined from not less than ten successive triple spot tests and shall include all such tests made.

The minimum spot test shall be that one of the three specimens of the triple spot test bearing the lightest coating, or the purchaser may select a single specimen taken from any part of the sheet, at least 2 in. from the side and 4 in. from the end. The average of minimum spot tests shall be determined from not less than ten successive minimum spot tests and shall include all such tests made.

(*d*) The weight of the zinc coating by triple and minimum spot tests shall be determined by the hydrochloric acid - antimony chloride, or sulfuric - permanganate method as described in the Standard Method of Determining Weight of Coating on Zinc-Coated Articles (Serial Designation: A 90) of the American Society for Testing Materials.[1] The weight of coating, in ounces per square foot, is numerically equal to that determined in grams from a sample $2\frac{1}{4}$ in. square.

TABLE II.—MINIMUM WEIGHT-OF-COATING TEST LIMITS, OZ. PER SQ. FT.

Class According to Desired or Ordered Coating	Rejection Limits by Different Tests[1]					
	Average of Weight Tests	Any One Weight Test	Average of Triple Spot Tests	Any One Triple Spot Test	Average of Minimum Spot Tests	Any One Minimum Spot Test
2.75	2.60	2.45	2.40	2.30	2.20	2.00
2.50	2.30	2.20	2.15	2.00	1.95	1.80
2.25	2.10	2.00	1.95	1.80	1.75	1.60
2.00	1.90	1.80	1.75	1.60	1.55	1.40
1.75	1.65	1.55	1.50	1.35	1.30	1.20
1.50	1.40	1.30	1.25	1.15	1.10	1.00
1.25	1.15	1.10	1.05	0.95	0.90	0.85

[1] Different methods of sampling and testing give different results as indicated in the above table. The purchaser shall specify which method he will use.

Bend Tests.

5. (*a*) *Base Metal Tests.*—Any part of the test specimen specified in Section 6 shall stand being bent cold through 180 deg. flat on itself without fracture of the base metal. The bend may be made in any direction.

(*b*) *Coating Tests.*—Sheets of Class A of No. 18 gage and lighter shall stand corrugating without flaking of the coating. Sheets of Class B of No. 12 gage and lighter shall stand corrugating and also subsequent longitudinal curving, as given below, without flaking of the coating. The corrugations for these tests shall not be less than $2\frac{2}{3}$ in. in width and not more than $\frac{1}{2}$ in. in depth.

GALVANIZED SHEET GAGE	DIAMETER OF CIRCLE
No. 12	36 in.
No. 14	24 "
No. 16	18 "

[1] See p. 343.

In the case of sheets of Class C, any part of the test specimen specified in Section 6, of sheets lighter than No. 16 gage, shall stand being bent in any direction without flaking of the coating on either side when bent through 180 deg. over four thicknesses of the material. A vise with smooth jaws and operated by hand shall be used for making the bend tests.

Test Specimens.

6. For the triple and minimum spot tests, three specimens exactly $2\frac{1}{4}$ in. square shall be cut from each test sheet, one being cut from the center and the others from diagonally opposite corners, but at least 4 in. from the end and 2 in. from the side. The bend test specimens shall be cut from the test sheet at least 4 in. from the end and 2 in. from the side. These specimens, so far as practicable, shall be cut from sheets that are imperfect outside the zone from which the specimens are to be taken.

Number of Tests.

7. (*a*) Weight tests shall be made of not less than 1 per cent of the sheets of each gage and ordered coating, or at approximately hourly intervals. If an inspector representing the purchaser witnesses and accepts weight tests, the triple and minimum spot tests shall not be made. If certificate of weight tests be accepted, the triple and minimum spot tests shall not be made unless doubt arises regarding uniformity of the material.

(*b*) The bend and spot tests, if required, shall be made from one sheet in each lot of 1000 sheets or fraction thereof, of each gage and ordered coating.

(*c*) If any sheet fails to meet the requirements of these specifications, a retest shall be made from two other sheets in the same lot, both of which shall meet the requirements.

PERMISSIBLE VARIATIONS

Dimensions.

8. The sheets shall conform to the dimensions specified with the following permissible variations:

(*a*) The width shall be not less than that ordered, but may be $\frac{1}{4}$ in. over for sheets 48 in. or less in width, and $\frac{3}{8}$ in. over for sheets over 48 in. in width.

(*b*) The length shall be not less than that ordered, but for sheets 96 in. or less in length it may be $\frac{3}{4}$ in. greater. For each 24 in. or fraction thereof above 96 in., the permissible variation may be increased $\frac{1}{4}$ in. over $\frac{3}{4}$ in.

(*c*) When sheets are required accurate to size, they shall be ordered "re-squared." Re-squared sheets shall be not less than the ordered width and length and shall be in excess by not more than $\frac{1}{16}$ in. unless wider than 48 in. or longer than 120 in., in either of which case the

excess tolerance shall be $\frac{1}{8}$ in. Should the sheets be re-squared before galvanizing, double the foregoing tolerances are permissible.

Weight. 9. The gage of galvanized sheets shall be determined by weight only. The weight per square foot of galvanized sheets shall conform to the tolerances given in Table III:

TABLE III.

Gage Range		Permissible Tolerances in Weights of Sheets, Plus or Minus, in Percentage of Theoretical Weight[1]			Gage Range	
Weight of Sheets, oz. per sq. ft.		All of One Gage and Size, in Shipment[2]	Single Packages	Single Sheets	Galvanized Sheet Gage Number	
Less than	Not less than				Lighter than	Not lighter than
....	42.5	5.0	7.0	10.0	..	16
42.5	22.5	3.5	5.5	10.0	16	22
22.5	....	2.5	4.0	10.0	22	..

WEIGHT OF GALVANIZED SHEETS, ALL CLASSES.

Galvanized Sheet Gage Number	Oz. per sq. ft.	Lb. per sq. ft.	Galvanized Sheet Gage Number	Oz. per sq. ft.	Lb. per sq. ft.
8	112.5	7.031	18	34.5	2.156
9	102.5	6.406	20	26.5	1.656
10	92.5	5.781	22	22.5	1.406
11	82.5	5.156	24	18.5	1.156
12	72.5	4.531	26	14.5	0.906
13	62.5	3.906	27	13.5	0.844
14	52.5	3.281	28	12.5	0.781
16	42.5	2.656	29	11.5	0.719
			30	10.5	0.656

[1] References are to gross weights of bundled material and to net weights of crated and boxed material. If the minimum or maximum only be ordered double tolerance is to be taken on permissible side.
[2] All of one gage and size in shipment shall apply to lots of not less than 6000 lb.

FINISH

Finish. 10. The finished sheets shall be of first-class commercial quality, free from injurious defects, such as blisters, flux and uncoated spots.

MARKING

Marking. 11. The top sheet of each bundle or the top sheet of a number of sheets when shipped loose, shall show legibly the name and brand of the manufacturer, class, gage, and size, unless otherwise ordered.

INSPECTION AND REJECTION

Inspection. 12. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to

satisfy him that the material is being furnished in accordance with these specifications. All tests (except check analyses and triple and minimum spot tests) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

13. Sheets represented by samples which fail to conform to the requirements of these specifications will be rejected and the manufacturer shall be notified. Rejection.

14. Samples tested in accordance with Section 7 (*b*), which represent rejected material, shall be preserved for two weeks from the date of the test report. Rehearing.

STANDARD METHODS OF CHEMICAL ANALYSIS OF PLAIN CARBON STEEL[1]

Serial Designation: A 33 – 24

These methods are issued under the fixed designation A 33; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ADOPTED, 1914; REVISED, 1924.

The following methods are subject to various errors which can not easily be overcome. Formulas which show the errors that are to be expected are therefore given under the general heading "Allowable Error" after the preferred methods. These are fair estimates of the performance of the methods in different hands.

DETERMINATION OF CARBON BY THE DIRECT-COMBUSTION METHOD.

The method of direct combustion of the metal in oxygen is recommended, the carbon dioxide obtained being absorbed in either (*a*) soda asbestos with suitable purifying and protecting trains following the furnace, or (*b*) barium hydroxide solution, the precipitated barium carbonate filtered off, washed, dissolved in a measured excess of hydrochloric acid and the excess titrated against standard alkali. Owing to the diversity of apparatus by which correct results may be obtained in the determinations of carbon, the recommendations are intended more to indicate what is acceptable than to prescribe definitely what shall be used.

APPARATUS AND REAGENTS COMMON TO BOTH METHODS.

Material for Lining Boats.—Alundum, "RR Alundum, alkali-free, specially prepared for carbon determination," as supplied by dealers is suitable, and is recommended. The 90-mesh or finer grades are used. Low-silica chrome ore, properly sized and freed from materials causing a blank, may also be employed. No substance containing alkali or alkaline earth metals, or carbon as carbonates or in other form, should be used as a lining material. Quartz sand, owing to its liability to fuse or to slag with the oxides of iron, causing bubbles of gas to be enclosed, is objectionable. Aluminum oxide, made by cal-

[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

cining alum or otherwise, often contains sulfate not easily destroyed, or may contain objectionable substances of an alkaline nature.

Catalyzers.—Suitable catalyzers are asbestos, copper oxide, platinized quartz or asbestos, or platinum gauze. One of these should be used in the forward part of the combustion apparatus, as well as in the preheater preceding the combustion tube (see below). Platinized materials sometimes give off volatile substances on heating, and whatever material is used should not be subject to this defect.

Combustion Apparatus.—Any apparatus heated by electricity or gas which will bring the sample to a temperature of 950 to 1100° C. may be used. Combustion tubes may be porcelain, glazed on one or both sides, quartz or platinum. Quartz is liable to devitrification when used continuously at temperatures above 1000° C., and may then become porous.

Boats or Other Containers of Samples Being Burned.—These may be porcelain, quartz, alundum, clay, platinum, or nickel, and should always receive a lining of granular alundum or any other material found to be suitable for the purpose. Nickel boats should not be made of sheet nickel containing more than 0.3 per cent of carbon. New boats should always be preheated in oxygen before use. In order to prevent spattering and attack of the tube, a platinum or nickel cover open at both ends and allowing free access of oxygen, is desirable.

Purifying Train Before Combustion Apparatus.—This consists of a tower filled with soda-asbestos, soda-lime or granular sodium hydroxide preceded by a preheater when necessary.

Oxygen.—Oxygen of not less than 97 per cent purity is recommended. Endeavor should be made to obtain oxygen which gives no blank, since the correction for or elimination of this is troublesome and uncertain. For the most accurate work, particularly with low-carbon products, such as ingot iron, etc., the blank should be completely eliminated by the use of a preheater before the furnace, with a carbon-dioxide absorbent interposed between furnace and preheater. The oxygen may be regulated either by means of a high pressure reducing valve or by means of a gasometer or gas holder.

FACTORS INFLUENCING RAPID COMBUSTION.

Size of Particles of Sample.—The finer the chips (short of dust, which causes low values on a hot boat) the better, except with samples which burn too vigorously (see under *Rate of Admitting Oxygen*). Particles too coarse to pass a 20-mesh sieve are not recommended, nor long curly drillings which will not pack closely. A ½-in. flat drill

may be used for taking the sample and the pressure and speed of the drill-press regulated to secure the desired result; or, better still, the sample may be obtained with a small milling machine suitable for sampling, or by a shaping machine. Oil, dust, and other foreign matter should be carefully excluded.

Manner of Distributing Sample in Boat.—This is of considerable importance. With all samples, close packing in a small space is conducive to rapid combustion. In the case of samples which burn too vigorously, a satisfactory regulation may sometimes be attained by spreading the sample loosely over the lining in the boat.

Rate of Admitting Oxygen.—The rate at which oxygen is admitted is also a factor in the velocity of combustion. Assuming the combustion apparatus to be heated to the temperature range above recommended (950 to 1100° C.), it is possible, if the material is closely packed and if oxygen is admitted at too rapid a rate, that the combustion may be so violent as to cause excessive spattering of fused oxides, and such fluidity of the molten slag that the boat or other container may be injured or destroyed; therefore a moderate rate of burning is to be sought. This is desirable also to insure the complete absorption of the carbon dioxide. The factors, temperature of combustion, apparatus, manner of distribution of sample, and rate of admission of oxygen, can be governed so as to burn successfully steels of a very wide range of compositions in either fine or coarse particles.

(*a*) *Determination of Carbon* (*Carbon Dioxide Absorbed in Soda-Asbestos*).

SPECIAL APPARATUS.

Purifying and Protecting Trains.—This method requires a purifying train before and after the combustion furnace. The purifying train before the furnace may be the same as that specified under (*b*), namely, a calcium-chloride tower filled with soda-asbestos, soda-lime or granular sodium hydroxide placed before the furnace, or between the furnace and preheater, if the latter is necessary for the purpose of oxidizing organic matter in the oxygen. The purifying train after the furnace should be so designed that it will accomplish the following: (1) Remove impalpable oxide of iron which readily passes through loosely packed plugs of glass wool or asbestos or even solutions through which the oxygen is rapidly bubbled; (2) remove oxides of sulfur which are always formed; (3) dry the gases before entering the carbon-dioxide absorber; (4) dry the gases issuing from the absorber

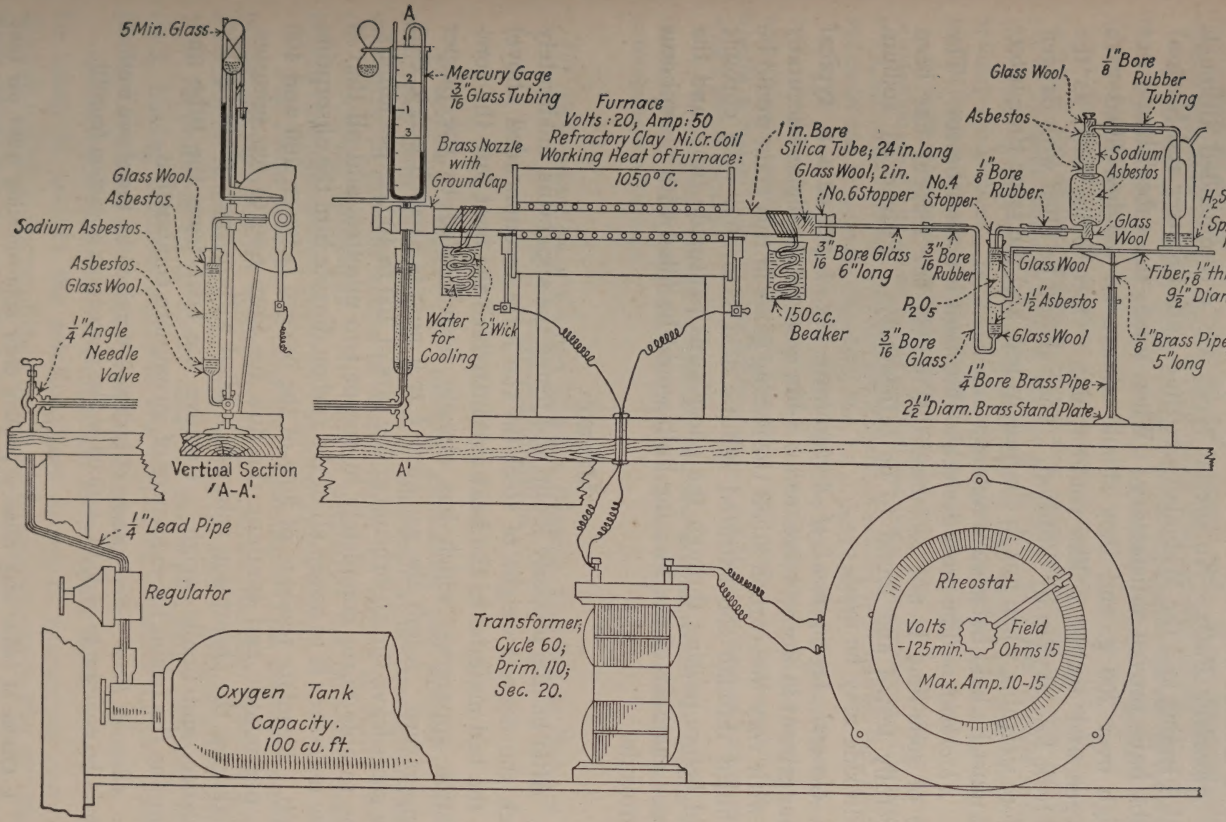


FIG. 1.—Apparatus for the Determination of Carbon by the Direct-Combustion Method.

to the same extent as when they entered; and (5) protect the weighed carbon dioxide and water absorbents from outside effects

Absorbing Bulbs.—No special types are recommended although both Fleming and the Midvale (sometimes called Stetzer and Norton) bulbs have proven satisfactory. When filled, the tubes should not weigh over 200 g. and they should always be weighed filled with oxygen and against a like counterpoise. Open bulbs such as the Midvale lose oxygen by diffusion. They should be filled with oxygen before weighing when not in continuous use, and the same time interval must be held between weighings.

Absorbents.—The most desirable absorbent is soda-asbestos. The use of soda-lime is not recommended unless the reagent has been carefully tested and found to be satisfactory. Pulverized sodium hydroxide may be used.

General Arrangement of Apparatus.—Fig. 1 presents a typical arrangement in works' laboratories. For work of the highest accuracy or with very low-carbon steels the issuing gases in this train would be bubbled through concentrated sulfuric acid saturated with chromic acid before passing through the phosphorus pentoxide tube, and the upper chamber of the Fleming bulb would be filled with phosphorus pentoxide.

METHOD.

After having properly set up and tested the apparatus, moderately pack the desired weight of steel (in the form recommended above) on the bed material in the boat and introduce the boat into the combustion apparatus, which has already been heated to the proper temperature. Admit the gas after $\frac{1}{2}$ to 1 minute at such a rate that the gases leave the absorbents at the rate of 200 to 400 cc. per minute. The sample burns completely in one or two minutes, and all that is now necessary is to sweep all of the carbon dioxide into the absorption bulb. Regulate the rate of flow of the oxygen between 200 and 400 cc. per minute and continue the flow for from five to ten minutes. Withdraw the absorption tube while filled with oxygen, place by the balance, and finally weigh. Remove the boat from the tube and examine the fusion for evidences of incomplete combustion.

Allowable Error.—Percentages of carbon determined by the above method should be accurate to $\pm$ [0.01 + (0.02 $\times$ the percentage of carbon found)].

NOTES.

1. Oxides of sulfur may cause a positive error approximating 0.005 per cent carbon in combustions of factor weights of ordinary steels when no provision is made for their removal. Sulfur trioxide can be almost entirely removed by inter-

posing some baffle which condenses it, such as asbestos, phosphorus pentoxide, or sulfuric acid. Sulfur dioxide is not so easily removed; the most satisfactory medium is concentrated sulfuric acid saturated with chromic acid. If not removed, sulfur dioxide may cause positive errors approximating 0.001 per cent carbon.

2. The oxides of sulfur which are fixed and accumulate in the end of the combustion tube should be periodically removed by heating the end of the tube in the hot zone of the furnace.

3. In accurate work or when dealing with low-carbon steels it is desirable to include in the weighed system a dehydrating agent which will dry the escaping gas to the same degree as when it entered the system. The loss of water from a good grade of soda-asbestos may cause losses as high as 0.01 per cent carbon in ordinary combustions. In careful work it is also desirable to protect the weighed system from moisture and carbon dioxide by means of suitable end tubes.

4. Soda-asbestos is commercially known as "Ascarite" and directions for its preparation are to be found in the *Journal Industrial and Engineering Chemistry*, Vol 8, pp. 1038–9 (1916). For the use of granular sodium hydroxide see the *Journal Industrial and Engineering Chemistry*, Vol. 13, p. 1052 (1921).

5. In some laboratories the absorbing bulbs are always kept in the balance case. In this case the balances are placed on the same table with the furnaces and each balance usually contains two absorbing bulbs which are connected by short lengths of rubber tubing to glass tubes extending out of the balance and connecting with a pair of furnaces.

6. The operator should occasionally test the apparatus and his technic by means of Bureau of Standards standard steels or steels which have been standardized in comparison with these.

(*b*) *Determination of Carbon (Carbon Dioxide Absorbed in Barium Hydroxide Solution).*

SPECIAL APPARATUS.

Purifying Train.—This method eliminates the necessity of a purifying train following the furnace, inasmuch as no precautions are necessary to prevent access of water vapor or oxides of sulfur from the absorbing apparatus. All that is needed is the purifying train before the combustion apparatus as mentioned above.

The Train after the Combustion Apparatus.—This consists merely of the Meyer tube for absorption of the carbon dioxide, protected by a soda-lime or soda-asbestos tube at the far end. Meyer tubes with 7 to 10 bulbs of 10 to 15-cc. capacity each, and large bulbs at the ends, having volumes equal to the combined capacity of the small bulbs, have been used and found satisfactory.

Filtering Apparatus.—In filtration for accurate work, care should be taken to protect the solution from access of extraneous carbon dioxide. This is accomplished in the apparatus shown in Fig. 2. For work requiring less accuracy, the barium carbonate may be filtered off on a filter made by fitting a carbon funnel with a perforated por-

celain disk and filtering by suction. The precipitate is then washed with distilled water from which the carbon dioxide has been removed by boiling.

REAGENTS.

Tenth-normal Hydrochloric Acid.—This may be standardized by any of the accepted methods, or as follows: Measure out 20 cc. of the approximately 0.1 *N* acid (free from chlorides) with a pipette, and precipitate the silver chloride by an excess of silver-nitrate solution in a volume of 50 to 60 cc. After digesting at 70 to 80° C., until the supernatant liquid is clear, filter off the chloride on a tared Gooch filter and wash with water containing 2 cc. of HNO_3 (sp. gr. 1.42) per 100 cc. of water until free from silver nitrate. After drying to constant weight at 130° C., note the increase of weight over the original tare and from this weight, corresponding to the silver chloride, calculate the strength of the hydrochloric acid, after which adjust it to the strength prescribed. The standardization should be based upon several concordant determinations using varying amounts of acid.

1 cc. 0.1 *N* HCl = 0.0006 g. carbon.

Methyl Orange.—Dissolve 0.02 g. of methyl orange in 100 cc. of hot distilled water and filter.

Tenth-normal Sodium Hydroxide Solution.—Standardize against the hydrochloric acid. Use methyl orange as the indicator. The sodium hydroxide solution should be stored in a large bottle from which it may be driven out by air pressure, protecting against carbon dioxide by soda-lime or soda-asbestos tubes.

Barium Hydroxide Solution.—Filter a saturated solution and store in a large reservoir from which it is delivered by air pressure, protecting from carbon dioxide by a soda-lime or soda-asbestos tube. In each determination fill three or four small bulbs of the Meyer tube, and add CO_2-free water until the remaining small bulbs are filled.

APPARATUS AND PROCEDURE FOR FILTRATION.

The apparatus is shown to approximately one-tenth size in Fig. 2, which is self-explanatory. The stop-cock is a three-way cock connected to the suction pipe. The rubber tubing connected to the Meyer tube should be of best-grade black rubber, and the lengths used should be so chosen as to permit of easy manipulation of the tube. The Meyer tube is connected or disconnected by the rubber stoppers which are left always attached to the rubber tubes. The carbon tube *C* is fitted with a perforated porcelain plate sliding easily.

The funnel is prepared for filtration by making on the porcelain disk a felt of asbestos about $\frac{1}{16}$ to $\frac{1}{8}$ in. in thickness, using amphibole (not serpentine) asbestos which has been carefully digested with strong hydrochloric acid for several hours and washed with water until it gives no acid reaction. On top of the asbestos pad is placed a layer of similarly treated quartz, mixed with asbestos, of the height shown. A mixture of quartz grains of various sizes (approximately 50 per cent passing a 20-mesh sieve and 50 per cent passing a 10-mesh and remaining on a 20-mesh sieve) is suitable. The mixture of quartz and asbestos may be obtained by filling the funnel from a beaker (directing against it a stream from a wash-bottle) while maintaining a gentle suction. In this way the asbestos is properly mixed with the quartz. A little experience and attention to these details will

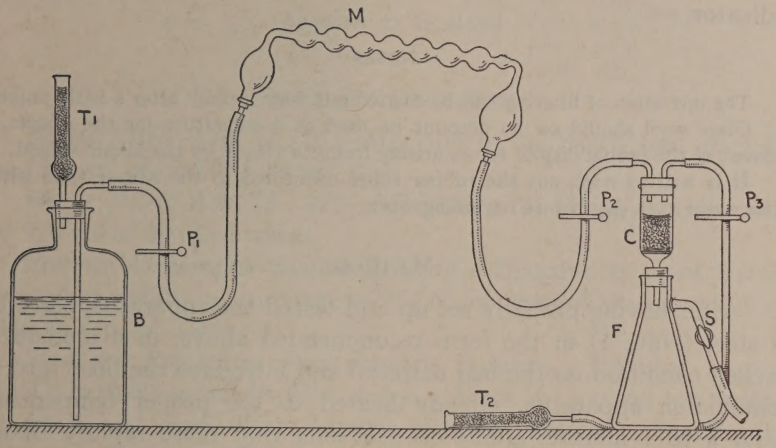


FIG. 2.—Apparatus for Filtration in Determination of Carbon by the Direct-Combustion Method.

enable one to prepare the quartz-bed in a manner that will greatly expedite filtration. The stopper is now inserted in the funnel, the Meyer tube connected as shown and the liquid and precipitate sucked into the funnel. Only a gentle suction should be used. When necessary P_3 is opened to admit air back of the column of liquid in the Meyer tube. When the contents of the Meyer tube have been transferred, the large bulb nearest B is half filled with water by opening P_1; the stop-cock S is operated during this and subsequent operations so as to maintain a gentle suction all the time. M is now manipulated so as to bring the wash water in contact with all parts of the interior, after which the water is sucked through C; P_2 is left open during this and subsequent washings. After eight washings as directed, allowing

the wash water to drain off thoroughly each time before adding more, *M* may be detached, the stopper removed from the funnel and the washings completed by filling *C* to the top with CO_2-free water, draining completely and repeating the operation once. With care the washing may be done with 150 cc. of water. Air is now admitted through the side opening of *S*, *C* is removed and the porcelain disk carrying the asbestos, quartz and barium carbonate is thrust, by means of a long glass rod, into a flask, removing any adhering particles from the sides of *C*, by a stream of water from a wash bottle. An excess of the standard acid is now added from a burette or pipette, using a portion to wash out *M*, and after the contents of the flask have been thoroughly agitated by shaking, the excess of acid is titrated against the standard alkali, using 3 drops of the methyl-orange indicator.

NOTES.

The operation of filtering can be carried out very rapidly after a little practice.

Glass wool should on no account be used as a substitute for the quartz, on account of the probability of errors arising from its attack by the alkali or acid.

It is well to wash out the rubber tubes connected to the Meyer tube with a little water each day before beginning work.

METHOD.

After having properly set up and tested the apparatus, place 2 g. of steel (Note 1) in the form recommended above, in a moderately packed condition on the bed material and introduce the boat into the combustion apparatus, already heated to the proper temperature. After ½ to 1 minute, admit oxygen somewhat more rapidly than it is consumed, as shown by the rate of bubbling in the Meyer tube (Note 2). A rate of 200 cc. per minute is satisfactory. The sample burns completely in 1 or 2 minutes, and all that is now necessary is to sweep all the carbon dioxide into the absorption apparatus. This be accomplished in 5 to 10 minutes by passing about 1 or 2 liters of oxygen. Detach the Meyer tube (Note 2) and filter and wash the barium carbonate, using the special filtering apparatus shown. After solution in a measured excess of standard hydrochloric acid (the Meyer tube being washed out with a portion of the acid, to remove adhering barium carbonate), titrate the excess of acid against alkali and from the data thus obtained calculate the percentage of carbon.

NOTES.

1. When working with steels high in carbon (above 1 per cent) it is advisable not to use more than 1 g. in order that filtration may be sufficiently rapid.

2. As a precaution against error resulting from too rapid passage of the gases, it is well to attach a second barium-hydroxide tube to retain any carbon dioxide that may pass the first.

3. For the most accurate work the Meyer tubes should be washed with dilute acid before beginning work each day. After a determination is finished, the tube should be completely filled two or three times with tap water, then rinsed with distilled water, in order to remove the carbon dioxide liberated when dissolving the carbonate from the previous determination.

4. The flask containing the carbonate should be thoroughly agitated after adding the acid, since the carbonate sometimes dissolves rather slowly if this is not done; this is particularly the case if it has packed much during filtration.

DETERMINATION OF MANGANESE BY THE BISMUTHATE METHOD.

(ABSENCE OF COBALT.)

SOLUTIONS REQUIRED.

Dilute Nitric Acid (1 : 3).—Mix 500 cc. of HNO_3 (sp. gr. 1.42) and 1500 cc. of distilled water.

Dilute Nitric Acid (3 : 97).—Mix 30 cc. of HNO_3 (sp. gr. 1.42) and 970 cc. of distilled water.

Ferrous Ammonium Sulfate Solution.—Dissolve 12 g. of ferrous ammonium sulfate in a mixture of 950 cc. of distilled water and 50 cc. of H_2SO_4 (sp. gr. 1.84).

Standard Potassium Permanganate Solution.—Dissolve 1 g. of $KMnO_4$ in 1000 cc. of distilled water. Allow it to stand for at least one week and then filter through purified asbestos. Standardize against the Bureau of Standards standard sodium oxalate as follows: In a 200-cc. beaker, dissolve 0.1 g. of sodium oxalate in 75 to 100 cc. of hot water (80 to 90° C.) and add 4 cc. of H_2SO_4 (1 : 1). Titrate at once with the permanganate solution, stirring the liquid vigorously and continuously. The permanganate must not be added more rapidly than 10 to 15 cc. per minute, and the last 0.5 to 1 cc. must be added dropwise, with particular care to allow each drop to be fully decolorized before the next is introduced. The excess of permanganate used to cause an end point color must be estimated by matching the color in another beaker containing the same bulk of acid and hot water. The temperature of the solution should not be below 60° C. by the time the end point is reached.

Standard Sodium Arsenite Solution.—Dissolve 2 g. of sodium arsenite in distilled water, filter if necessary, and dilute to one liter. Standardize against a standard permanganate solution such as the

above by titrating 10-cc. portions of the permanganate solution under the acidity and dilution conditions obtaining in the method. A clear green color free from brownish or purplish tints will be found a satisfactory and reproducible end point. The solution may also be standardized against Bureau of Standards standard plain carbon steels.

METHOD.

In a 300-cc. Erlenmeyer flask dissolve 1 g. of steel in 50 cc. of dilute HNO_3 (1 : 3), and boil to expel the oxides of nitrogen. Cool, and add about 0.5 g. of sodium bismuthate and heat for a few minutes, or until the pink color has disappeared, with or without precipitation of manganese dioxide. Add small portions of ferrous sulfate (or any suitable reducing agent) in sufficient quantity to clear the solution, and boil to expel the oxides of nitrogen. Cool to 15° C., add an excess of sodium bismuthate and agitate for a few minutes. Add 50 cc. of dilute HNO_3 (3 : 97), filter through an alundum filter or asbestos pad, and wash with the same acid. Titrate by method (*a*) or (*b*) below.

(*a*) *Ferrous Sulfate-Permanganate Titration* (less than 0.05 per cent chromium).

Add from a burette or pipette 10 to 50 cc. (depending on the amount of permanganic acid) of ferrous ammonium sulfate solution and then titrate with the standard $KMnO_4$ solution. In exactly the same manner carry through a blank determination using the same amounts of acid and bismuthate as was done with the regular sample. Finally add the exact volume of ferrous ammonium sulfate solution which was employed and titrate with the standard $KMnO_4$ solution. The difference between the volumes required in the two titrations represents the manganese in the sample.

(*b*) *Arsenite Titration* (more than 0.05 per cent chromium).

Titrate immediately with the standard sodium arsenite solution to the clear green color used as an end point in the standardization of the solution.

Allowable Error.—Percentages of manganese determined by the above method should be accurate to $\pm$ [0.01 + (0.02 $\times$ the percentage of manganese found)].

NOTES.

In the method, the preliminary treatment with sodium bismuthate has been found by a number of investigators to be apparently unnecessary; however, the available data to confirm this position are not considered sufficient to warrant its omission.

In making the asbestos filter pad it is advisable to have a thin bed, and as much surface as possible. This insures rapid filtration, and the filter may be used until it becomes clogged with bismuthate.

The filtrate must be perfectly clear, since the least particle of bismuthate carried through the filter will vitiate the results.

This method can not be used in the presence of cobalt.

In the arsenite titration, permanganic acid does not react in accordance with the ratio Mn_2O_7 : 2 MnO, but more nearly as indicated by the ratio Mn_2O_7 : Mn_2O_3. Consequently the theoretical titre of the arsenite can not be used and the manganese titre must be obtained by titration of material of known manganese content under the conditions that obtain in the method.

DETERMINATION OF MANGANESE BY THE PERSULFATE METHOD.

(ROUTINE AND IN THE PRESENCE OF COBALT.)

SOLUTIONS REQUIRED.

Dilute Nitric Acid (sp. gr. 1.20).—Mix 380 cc. of HNO_3 (sp. gr. 1.42) and 620 cc. of distilled water.

Silver Nitrate (0.133-per-cent).—Dissolve 1.33 g. of $AgNO_3$ in 1000 cc. of distilled water.

Ammonium Persulfate Solution (10-per-cent).—Prepare as needed by dissolving 10 g. of the salt in 100 cc. of distilled water.

Sodium Chloride (0.2-per-cent).—Dissolve 2 g. of NaCl in 1000 cc. of distilled water.

Standard Sodium Arsenite.—Dissolve 0.8 g. of sodium arsenite in distilled water, filter if necessary; dilute to one liter and standardize against a standard steel or by means of 5 cc. of standard 0.03 *N* permanganate solution which has been reduced and then carried through the steps of the method described below.

METHOD.

In a small Erlenmeyer flask or large test tube (8 by 1 in.) dissolve 0.1 to 0.3 g. of steel, depending on the manganese content of the sample, in 15 cc. of dilute HNO_3 (sp. gr. 1.20) with the aid of heat from a hot-plate or water-bath. The solution of carbon may be hastened by the addition of 1 cc. of the $(NH_4)_2S_2O_8$ solution (10-per-cent). When solution is complete and the liquid is clear, add 15 cc. of $AgNO_3$ solution (0.133-per-cent). If a tube is used, add 10 cc. of the $(NH_4)_2S_2O_8$ solution (10-per-cent) and heat in the water-bath until the color develops. If a flask is employed, bring the solution to boiling, add 10 cc. of the persulfate solution and then set aside in a

warm place until the color develops. When the color has developed, cool the solution in running water, transfer to a 250-cc. beaker and dilute to a volume of 75 cc. Add 10 cc. of NaCl solution (0.2-per-cent) and titrate with the standard arsenite solution.

NOTES.

The persulfate oxidation requires careful attention; the solution must not be too acid and sufficient $AgNO_3$ must be present (about 15 times as much $AgNO_3$ as Mn). Consequently, in steels of high manganese content the amount of $AgNO_3$ and NaCl should be increased.

If it is desired, larger amounts of the sample can be used and correspondingly greater amounts of $AgNO_3$, NaCl and $(NH_4)_2S_2O_8$ (preferably in the form of stronger solutions).

DETERMINATION OF PHOSPHORUS BY THE MOLYBDATE-MAGNESIA METHOD.

SOLUTIONS REQUIRED.

Dilute Nitric Acid (sp. gr. 1.20).—Mix 380 cc. of HNO_3 (sp. gr. 1.42) and 620 cc. of distilled water.

Dilute Nitric Acid (2 : 100).—Mix 20 cc. of HNO_3 (sp. gr. 1.42) and 1000 cc. of distilled water.

Potassium Permanganate (2.5-per-cent).—Dissolve 25 g. of $KMnO_4$ in 1000 cc. of distilled water.

Dilute Ammonium Hydroxide (1 : 2).—Mix 300 cc. of NH_4OH (sp. gr. 0.90) and 600 cc. of distilled water.

Dilute Ammonium Hydroxide (1 : 19).—Mix 100 cc. of NH_4OH (sp. gr. 0.90) and 1900 cc. of distilled water.

Ammonium Bisulfite (3-per-cent).—Dissolve 30 g. of ammonium bisulfite in 1000 cc. of distilled water.

Ammonium Molybdate.—

Solution No. 1.—Place in a beaker 100 g. of 85-per-cent molybdic acid, mix it thoroughly with 240 cc. of distilled water, add 140 cc. of NH_4OH (sp. gr. 0.90), filter, and add 60 cc. of HNO_3 (sp. gr. 1.42).

Solution No. 2.—Mix 400 cc. of HNO_3 (sp. gr. 1.42) and 960 cc. of distilled water.

When the solutions are cold, add Solution No. 1 to Solution No. 2, stirring constantly; then add 0.1 g. of ammonium phosphate dissolved in 10 cc. of distilled water, and let stand at least 24 hours before using.

Magnesia Mixture.—Dissolve 50 g. of $MgCl_2 \cdot 6H_2O$ and 125 g. of NH_4Cl in 750 cc. of distilled water, and then add 150 cc. of NH_4OH (sp. gr. 0.90).

METHOD.

In a 300-cc. Erlenmeyer flask dissolve 5 g. of steel in 75 cc. of dilute HNO_3 (sp. gr. 1.20). Heat to boiling; while boiling add about 12 cc. of the potassium permanganate solution, and continue boiling until manganese dioxide precipitates. Dissolve this precipitate by additions of ammonium bisulfite or ferrous sulfate solution, boil until clear and free from brown fumes and cool to 80° C. Add 100 cc. of the ammonium molybdate solution at room temperature, shake or agitate for 5 minutes, allow to settle, filter on a 9-cm. paper and wash the flask and precipitate at least three times with the dilute HNO_3 (2 : 100), to free from iron.

Dissolve the precipitate on the filter with dilute NH_4OH (1 : 2), letting the solution run into the original flask and avoiding the use of more than 10 to 20 cc. of the reagent. Pour a solution of 0.5 g. of citric acid in 15 cc. of water and 10 cc. of HCl (sp. gr. 1.19) through the filter in order to dissolve any ferric phosphate on the paper and render acid the ammoniacal solution of the phosphate. Transfer the solution to a 100-cc. beaker, add 10 cc. of the magnesia mixture and precipitate the phosphate by adding NH_4OH (sp. gr. 0.90) slowly and with constant stirring, until a crystallin precipitate is formed or the solution is alkaline. Finally add 10 per cent by volume excess and set aside in a cool place for 2 to 6 hours. Filter, wash with dilute NH_4OH (1 : 19), ignite and weigh. Dissolve the precipitate of magnesium pyrophosphate in 5 cc. of dilute HNO_3 (5 : 6), and 20 cc. of distilled water, filter and wash with hot water. Ignite and weigh. The difference in weights represents pure magnesium pyrophosphate containing 27.87 per cent of phosphorus.

Allowable Error.—Percentages of phosphorus determined by the above method should be accurate to $\pm$ [0.002 + (0.02 $\times$ the percentage of phosphorus found)].

NOTES.

The ammonium molybdate solution should be kept in a cool place and should always be absolutely clear before using.

If arsenic is present in the steel, it will come down in part with the phosphomolybdate and contaminate the pyrophosphate. In very accurate work, or when arsenic is present in appreciable amount, steps must be taken for its removal before precipitation with magnesia mixture.

DETERMINATION OF PHOSPHORUS BY THE ALKALIMETRIC METHOD. (ROUTINE.)

SOLUTIONS REQUIRED.

Dilute Nitric Acid (sp. gr. 1.20).—See "Determination of Phosphorus by the Molybdate-Magnesia Method."[1]

Dilute Nitric Acid (2 : 100).—See "Determination of Phosphorus by the Molybdate-Magnesia Method."[1]

Potassium Permanganate.—See "Determination of Phosphorus by the Molybdate-Magnesia Method."[1]

Ammonium Bisulfite.—See "Determination of Phosphorus by the Molybdate-Magnesia Method."[1]

Ammonium Molybdate.—See "Determination of Phosphorus by the Molybdate-Magnesia Method."[1]

Potassium Nitrate (1-per-cent).—Dissolve 10 g. of KNO_3 in 1000 cc. of distilled water.

Phenolphthalein Indicator.—Dissolve 0.2 g. of phenolphthalein in 50 cc. of 95-per-cent ethyl alcohol and 50 cc. of distilled water.

Standard Sodium Hydroxide.—Dissolve 6.5 g. of purified NaOH in 1000 cc. of distilled water, add a slight excess of 1-per-cent solution of $Ba(OH)_2$, let stand for 24 hours, decant the liquid, standardize it against a steel of known phosphorus content, as determined by the molybdate-magnesia method and dilute so that 1 cc. will be equivalent to 0.01 per cent of phosphorus on the basis of a 2-g. sample (see Notes). Protect the solution from carbon dioxide with a soda-lime or soda-asbestos tube.

Standard Nitric Acid.—Mix 10 cc. of HNO_3 (sp. gr. 1.42) and 1000 cc. of distilled water. Titrate the solution against the standard sodium hydroxide solution using phenolphthalein as indicator, and make it equivalent to the sodium hydroxide solution by adding distilled water.

METHOD.

In a 300-cc. Erlenmeyer flask dissolve 2 g. of steel in 50 cc. of dilute HNO_3 (sp. gr. 1.20). Heat the solution to boiling and while boiling add about 6 cc. of the $KMnO_4$ solution and continue boiling until manganese dioxide precipitates. Dissolve this precipitate by additions of ammonium bisulfite or ferrous sulfate solution, boil until

[1] See p. 288.

clear and free from brown fumes, cool to 80° C., add 50 cc. of the ammonium molybdate solution at room temperature, shake or agitate for 5 minutes, allow to settle and filter on a 9-cm. paper. Wash the flask and precipitate three times with dilute HNO_3 (2 : 100) to free it from iron, and continue the washing with the 1-per-cent potassium nitrate solution until the paper, precipitate and flask are free from acid.

Transfer the paper and precipitate to the flask, add 20 cc. of distilled water, 5 drops of phenolphthalein solution as indicator, and an excess of standard sodium hydroxide solution. Insert a rubber stopper and shake vigorously until solution of the precipitate is complete. Wash off the stopper with distilled water and determine the excess of sodium hydroxide solution by titrating with standard nitric acid solution. Each cubic centimeter of standard sodium hydroxide solution represents 0.01 per cent of phosphorus.

NOTES.

The ammonium molybdate solution should be kept in a cool place and should always be absolutely clear before using.

All distilled water used in titration should be freed from carbon dioxide by boiling or otherwise.

Appropriate Bureau of Standard Standard Steels are recommended for the standardization of the sodium hydroxide solution.

The composition of phosphomolybdate varies with changes in conditions such as acidity, temperature and concentration of the molybdate reagent; consequently care should be taken to keep conditions alike in standardization and in analysis. The ratio 23 molecules of sodium hydroxide to 1 atom of phosphorus represents the reaction very closely if the phosphomolybdate is precipitated at 35 to 45° C.

DETERMINATION OF SULFUR

BY THE

OXIDATION METHOD.

SOLUTIONS REQUIRED.

Dilute Hydrochloric Acid (2 : 98).—Mix 20 cc. of HCl (sp. gr. 1.19) and 980 cc. of distilled water.

Barium Chloride Solution (10-per-cent).—Dissolve 100 g. of $BaCl_2 \cdot 2H_2O$ in 1000 cc. of distilled water.

Barium Chloride—Hydrochloric Acid Washing Solution.—Mix 10 cc. of the above solution, 10 cc. of HCl (sp. gr. 1.19) and 1000 cc. of distilled water.

METHOD.

Dissolve 4.57 g. of the sample in 50 cc. of HNO_3 (sp. gr. 1.42) in a covered beaker or flask. In case solution is slow or difficult, HCl (sp. gr. 1.19) may be added dropwise at intervals. When solution is complete, add 0.5 g. of Na_2CO_3, evaporate to dryness and bake for 1 hour on the hot plate. Add 30 cc. of HCl (sp. gr. 1.19) and repeat the evaporation and baking. Add another 30 cc. of HCl (sp. gr. 1.19) and evaporate to syrupy consistency. Add 5 cc. of HCl (sp. gr. 1.19) 20 cc. of water, 5 g. of 20 to 30-mesh zinc (free from sulfur), and warm on the steam-bath until the iron is reduced to the ferrous state, and the evolution of hydrogen has nearly ceased. Filter by decantation

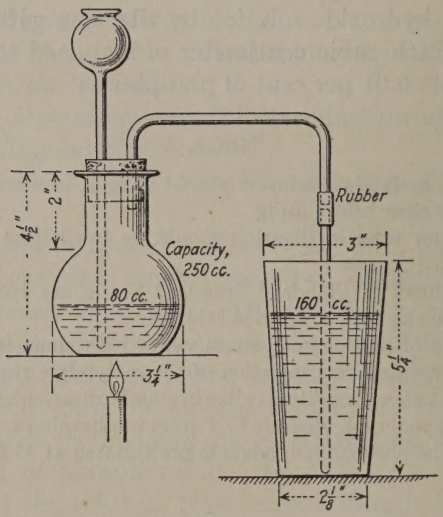


FIG. 3.—Apparatus for Determination of Sulfur by the Evolution Method.

on a small filter from the silica and undissolved zinc, wash with small portions of approximately 75 cc. of dilute HCl (2 : 98), warm to 60 to 70° C. and add 10 cc. of $BaCl_2$ solution (10-per-cent). Let stand for 18 to 24 hours, filter on a paper of close texture and discard the filtrate. Wash with hot $BaCl_2$-HCl washing solution until free from iron and then with hot water until free from chlorides. Reserve the paper and precipitate and evaporate the washings to dryness. Dissolve the slight residue in 50 cc. of hot dilute HCl (2 : 98), add 1 cc. of $BaCl_2$ solution (10-per-cent), and digest at 70 to 80° C. for an hour or so, avoiding any undue evaporation. Filter on a small paper of close texture, wash with hot $BaCl_2$-HCl washing solution until free from iron and then with hot water until free from chlorides. Ignite

both papers in a tared platinum crucible and treat with one drop of dilute H_2SO_4 (1 : 1) and 1 cc. of hydrofluoric acid. Evaporate to dryness, ignite and weigh. A blank should be carried through all steps of the determination and any $BaSO_4$ found deducted. The corrected weight of the ignited $BaSO_4$ multiplied by 3 represents the percentage of sulfur.

Allowable Error.—Percentages of sulfur determined by the above method should be accurate to $\pm$ [0.002 + (0.02 $\times$ the percentage of sulfur found)].

NOTES.

The precipitation of $BaSO_4$ must not be carried out in a solution containing more than 2 cc. of HCl (sp. gr. 1.19) per 100 cc.

The recovery of $BaSO_4$ which is obtained ordinarily represents approximately 0.001 per cent of sulfur.

Precipitation of $BaSO_4$ in unreduced iron solutions of carefully regulated acidity gives low values of the order of 0.001 to 0.002 per cent of sulfur.

DETERMINATION OF SULFUR BY THE EVOLUTION-TITRATION METHOD. (ROUTINE.)

APPARATUS.

Figure 3 shows a typical apparatus for this determination. A spray trap may be put in the outlet tube to prevent iron from passing over into the ammoniacal solution.

SOLUTIONS REQUIRED.

Dilute Hydrochloric Acid (1 : 1).—Mix 500 cc. of HCl (sp. gr. 1.19) and 500 cc. of distilled water.

Ammoniacal Cadmium Chloride.—Dissolve 10 g. of cadmium chloride in 400 cc. of distilled water and add 600 cc. of NH_4OH (sp. gr. 0.90).

Ammoniacal Zinc Sulfate.—Dissolve 20 g. of $ZnSO_4 \cdot 7H_2O$ in 1080 cc. of water and add 920 cc. of ammonium hydroxide (sp. gr. 0.90).

Potassium Iodate.—Dissolve 1.12 g. of KIO_3 and 12 g. of KI in 1000 cc. of distilled water. For general work the theoretical sulfur titre of this solution should be used; for specialized work on one kind of material, the solution may be standardized against like material. The theoretical titre is based on standard sodium oxalate and is obtained as follows: To 300 cc. of water in a 600-cc. flask, preferably glass stoppered, add 10 cc. of HCl (sp. gr. 1.19) and 1 g. of KI. Cool

and add 25 cc. of 0.03 *N* $KMnO_4$ solution which has been standardized against sodium oxalate. Swirl gently, stopper, and let stand for five minutes. Titrate the liberated iodine with thiosulfate solution until the color fades. Then add 10 cc. of starch solution and continue the titration until the blue color is destroyed. Repeat the titration with the sole difference that 25 cc. of the iodate solution is substituted for the standard permanganate solution. Calculate the normality of the iodate solution, and dilute it if desired so that its normality is 0.0312 or 1 cc. is equivalent to 0.01 per cent of sulfur on a 5-g. sample. For standardization against like material, 5-g. portions of the proper standard steel are carried through all steps of the method.

Starch Indicator.—(1) To 1000 cc. of boiling distilled water, add a cold suspension of 6 g. of starch in 100 cc. of water and boil vigorously for five minutes. Cool the solution, add 6 g. of $ZnCl_2$ dissolved in 50 cc. of cold water, thoroughly mix and set aside for 24 hours. Decant the clear supernatant liquid into a suitable container, add 3 g. of KI and mix thoroughly. (2) (Optional). Prepare an emulsion of 6 g. of soluble starch in 25 cc. of water, add a solution of 1 g. of NaOH in 10 cc. of water, and stir the solution until it gelatinizes. Dilute to 1000 cc., add 3 g. of KI, and mix thoroughly.

METHOD.

Place 5 g. of steel in the flask and connect the latter as shown in Fig. 3. Place 10 cc. of the ammonical cadmium chloride or zinc sulfate solution and 150 cc. of distilled water in the tumbler. Add 80 cc. of the dilute HCl (1:1) to the flask through the thistle tube, heat the flask with its contents gently until the solution of the steel is complete, then boil the solution for ½ minute. Disconnect the delivery tube and remove the tumbler which contains all the sulfur as cadmium sulfide. Add 5 cc. of starch solution, then 40 cc. of dilute HCl (1:1) and titrate *immediately* with the potassium iodate solution to a permanent blue color.

NOTES.

This method succeeds best when the evolution of gas is rapid and the conditions are kept constant.

Some analysts prefer to add the dilute HCl at a temperature of 80 to 90° C. and to heat the flask on an electric heater instead of over gas. The use of concentrated HCl necessitates a condensing arrangement and does not offer any general advantages over the diluted acid.

With most plain carbon steel, the results for sulfur which are obtained by the evolution method and the use of the theoretical sulfur titre, check the gravimetric results within ±0.002 per cent. Some steels dissolve too slowly and

some, as, for example, certain steels containing high sulfur and carbon, do not yield all of their sulfur. In such cases the samples must be annealed as follows:

Transfer 5 g. of drillings to a 12.5-cm. filter paper, and wrap the sample securely in the paper so that at least three thicknesses of paper cover the steel. Place the package in a 25-cc. porcelain crucible, cover the crucible tightly so that no air can enter, and heat for 20 minutes at a bright red heat over a burner or preferably in a muffle. The filter paper should be charred but not burned. Cool and proceed as in the regular method.

DETERMINATION OF SILICON BY THE NITRO-SULFURIC METHOD.

SOLUTIONS REQUIRED.

Nitro-Sulfuric Acid.—Mix 1000 cc. of H_2SO_4 (sp. gr. 1.84), 1500 cc. of HNO_3 (sp. gr. 1.42) and 5500 cc. of distilled water.

Dilute Hydrochloric Acid (5 : 95).—Mix 50 cc. of HCl (sp. gr. 1.19) and 950 cc. of distilled water.

METHOD.

Add cautiously 80 cc. of the nitro-sulfuric acid to 4.676 g. of steel, in a platinum or porcelain dish of 300 cc. capacity, cover with a watch glass, heat until the steel is dissolved and evaporate slowly until copious fumes of sulfuric acid are evolved. Cool, add 125 cc. of distilled water and 5 cc. of HCl (sp. gr. 1.19), heat with frequent stirring until all salts are dissolved and immediately filter on a 9-cm. paper. Wash the precipitate with cold dilute HCl (5 : 95) and hot water alternately to complete the removal of iron salts, and finally with hot water until free from acid. Transfer the filter to a platinum crucible, burn off the paper carefully, finally igniting with the crucible covered over a blast lamp or in a muffle furnace at 1000° C. for at least 10 minutes; cool in a desiccator and weigh. Add sufficient dilute H_2SO_4 (1 : 1) to moisten the silica and then a small amount of hydrofluoric acid. Evaporate to dryness, ignite and weigh. The difference in weights in milligrams divided by 100 equals the percentage of silicon.

Allowable Error.—Percentages of silicon determined by the above method should be accurate to $\pm$ [0.005 + (0.02 $\times$ the percentage of silicon found)].

NOTE.

A blank determination on all reagents used should be made and the results corrected accordingly.

DETERMINATION OF SILICON BY THE SULFURIC ACID METHOD. (OPTIONAL.)

SOLUTIONS REQUIRED.

Dilute Hydrochloric Acid (5 : 95).—Mix 50 cc. of HCl (sp. gr. 1.19) and 950 cc. of distilled water.

METHOD.

To 2.338 g. of steel, in a beaker of low form of 500-cc. capacity, add 60 cc. of distilled water, and then cautiously 15 cc. of H_2SO_4 (sp. gr. 1.84). Cover with a watch glass, heat until the steel is dissolved and evaporate until copious fumes of sulfuric acid are evolved. Cool, add 100 cc. of distilled water and heat with frequent stirring until the salts are in solution. Immediately filter on a 9-cm. paper, wash the precipitate with cold dilute HCl (5 : 95), until free from iron, and finally with hot water until free from acid. Ignite and weigh. Add sufficient dilute H_2SO_4 (1 : 1) to moisten the silica and then a small amount of hydrofluoric acid. Evaporate to dryness, ignite and weigh. The difference in weights in milligrams divided by 50 equals the percentage of silicon.

Allowable Error.—Percentages of silicon determined by the above method should be accurate to $\pm$ [0.005 + (0.02 $\times$ the percentage of silicon found)].

NOTE.

A blank determination on all reagents used should be made and the results corrected accordingly.

DETERMINATION OF COPPER.

SOLUTIONS REQUIRED.

Dilute Sulfuric Acid (1 : 5).—Slowly stir 200 cc. of H_2SO_4 (sp. gr. 1.84) into 1000 cc. of distilled water.

Dilute Sulfuric Acid (2 : 98).—Mix 20 cc. of H_2SO_4 (sp. gr. 1.84) and 980 cc. of distilled water.

Acidulated Hydrogen Sulfide Water.—Saturate 500 cc. of the above solution with hydrogen sulfide.

Sodium Hydroxide (5-per-cent).—Dissolve 50 g. of stick NaOH in 1000 cc. of distilled water and filter through asbestos if necessary.

Sodium Thiosulfate (50-per-cent).—Dissolve 100 g. of $Na_2S_2O_3 \cdot 5H_2O$ in 100 cc. of distilled water and filter if necessary.

Dilute Nitric Acid (1 : 1).—Mix 500 cc. of HNO_3 (sp. gr. 1.42) and 500 cc. of distilled water.

METHOD.

(*a*) *Precipitation by Hydrogen Sulfide.*

Dissolve 10.00 g. of steel in 100 cc. of dilute H_2SO_4 (1 : 5), and when solution is complete, dilute to at least 500 cc. with water. Heat to boiling and saturate with H_2S. Digest a while, filter on paper or paper pulp and wash with acidulated hydrogen sulfide water. Ignite the residue and paper in a porcelain crucible and fuse with a small amount of alkali pyrosulfate. Dissolve the cooled melt in the crucible in 1 to 2 cc. of HCl (sp. gr. 1.19) and a few cc. of water, transfer to a 200-cc. beaker, dilute to 100 cc. and add NaOH (5-per-cent) solution in slight excess. Boil, digest, and filter, in order to separate such elements as vanadium, tungsten and molybdenum. Dissolve the precipitate in hot dilute HNO_3 (1 : 1), add 5 cc. of H_2SO_4 (sp. gr. 1.84), evaporate to the appearance of fumes of sulfuric acid, cool, dilute to 40 cc., filter and add 10 cc. of NH_4OH (sp. gr. 0.90). Heat the feebly acid solution to boiling and saturate with H_2S. Digest a while, filter, wash thoroughly with acidulated hydrogen sulfide water, and proceed according to method *1* or *2* below.

(*b*) *Precipitation by Thiosulfate.*

Transfer 5 g. of the sample to a 600-cc. beaker, add 100 cc. of H_2SO_4 (1 : 5), and heat until the sample is dissolved. Dilute to 300 cc., heat to boiling, add 15 cc. of thiosulfate solution (50-per-cent), and continue the boiling for five minutes or until the precipitate of copper sulfide has coagulated. Collect the precipitate upon an 11-cm. paper and wash *slightly* with dilute H_2SO_4 (2 : 98). Ignite the residue and paper in a porcelain crucible and fuse with a *small* amount of alkali pyrosulfate. Dissolve the cooled melt in the crucible in 1 to 2 cc. of HCl (sp. gr. 1.19) and a few cc. of water, transfer to a 200-cc. beaker, dilute to 100 cc. and add NaOH (5-per-cent) solution in slight excess. Boil, digest and filter in order to separate such elements as vanadium, tungsten and molybdenum. Dissolve the precipitate in hot dilute HNO_3 (1 : 1), carefully add 20 cc. of H_2SO_4 (sp. gr. 1.84), evaporate to the appearance of fumes of H_2SO_4, cool, dilute and filter. Dilute the solution to a volume of 300 cc. and precipitate the copper with thiosulfate as above. Filter, wash with dilute H_2SO_4 (2 : 98) until sodium salts have been removed and proceed according to method *1* or *2* below.

(*1*) *Electrolytic Method.*

Dissolve the sulfides obtained as above in hot dilute HNO_3 (1 : 1), and electrolyze after the addition of H_2SO_4 according to usual procedures.

(2) *Gravimetric Method.*

Ignite the sulfides obtained as above and weigh as copper oxide. As this compound is somewhat hygroscopic, care must be observed to prevent the absorption of moisture.

Allowable Error.—Percentages of copper determined by the above method should be accurate to $\pm$ [0.005 + (0.02 $\times$ the percentage of copper found)].

DETERMINATION OF COPPER.

(ROUTINE.)

SOLUTIONS REQUIRED.

Potassium Ferrocyanide.—Dissolve 10 g. of potassium ferrocyanide in 100 cc. of distilled water.

Standard Copper Nitrate.—Dissolve 2 g. of purest electrolytic copper in 20 cc. of HNO_3 (1 : 1), and dilute to 1000 cc. with distilled water. Each cubic centimeter is equivalent to 0.02 per cent of copper on the basis of a 10-g. sample.

METHOD.

Proceed as in (*a*) Precipitation by Hydrogen Sulfide or (*b*) Precipitation by Thiosulfate, under "Determination of Copper"[1] until the alkali pyrosulfate fusion has been made. Extract the cooled melt with hot water, filter, and complete the determination colorimetrically as follows:

Evaporate the filtrate to about 25 cc., make faintly ammoniacal, filter into a 100-cc. Nessler tube and wash with hot water.

(*a*) *If the solution is a strong blue,*

To another 100-cc. Nessler tube add 50 cc. of distilled water, 5 cc. of NH_4OH (sp. gr. 0.90) and from a burette the standard copper nitrate solution until the blue colors match.

(*b*) *If the solution is a faint blue,*

To the filtrate in a Nessler tube add dilute H_2SO_4 (1 : 5) to faint acidity and then a few drops of the potassium ferrocyanide solution. To another 100-cc. Nessler tube add 50 cc. of distilled water, a few drops of the potassium ferrocyanide solution, and from a burette the standard copper nitrate solution until the reddish brown colors match.

[1] See p. 296.

DETERMINATION OF NICKEL.

See the determination of Nickel in Nickel Steel by the Gravimetric Dimethylglyoxime Method under the Standard Methods of Chemical Analysis of Alloy Steels (Serial Designation: A 55) of the American Society for Testing Materials.[1]

See the determination of Nickel in Nickel Steel by the Cyanide Titration Method (Routine) under the Standard Methods of Chemical Analysis of Alloy Steels (Serial Designation: A 55) of the American Society for Testing Materials.[1]

DETERMINATION OF CHROMIUM.

See the Determination of Chromium in Chrome-Nickel Steel by the Persulfate Oxidation Method under the Standard Methods of Chemical Analysis of Alloy Steels (Serial Designation: A 55) of the American Society for Testing Materials.[1]

[1] See p. 300.

STANDARD METHODS OF CHEMICAL ANALYSIS OF ALLOY STEELS[1]

Serial Designation: A 55 – 24

These methods are issued under the fixed designation A 55; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ADOPTED, 1915; REVISED, 1924.

SILICO-MANGANESE STEEL.

All determinations are carried out as in the Standard Methods of Chemical Analysis of Plain Carbon Steel (Serial Designation: A 33) of the American Society for Testing Materials.[2]

NICKEL STEEL.

DETERMINATION OF CARBON.

See the Determination of Carbon in Plain Carbon Steel by the Direct-Combustion Method.[3]

DETERMINATION OF MANGANESE.

See the Determination of Manganese in Plain Carbon Steel by the Bismuthate Method.[3]

See the Determination of Manganese in Plain Carbon Steel by the Persulfate Method (Routine).[3]

DETERMINATION OF PHOSPHORUS.

See the Determination of Phosphorus in Plain Carbon Steel by the Molybdate-Magnesia Method.[3]

See the Determination of Phosphorus in Plain Carbon Steel by the Alkalimetric Method (Routine).[3]

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[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

[2] See p. 276.

[3] Standard Methods of Chemical Analysis of Plain Carbon Steel (Serial Designation: A 33) of the American Society for Testing Materials, see p. 276.

DETERMINATION OF SULFUR.

See the Determination of Sulfur in Plain Carbon Steel by the Oxidation Method.[1]

See the Determination of Sulfur in Plain Carbon Steel by the Evolution Titration Method (Routine).[1]

NOTES.

The Evolution-Titration Method should not be used with steels containing appreciable amounts of tungsten or molybdenum or more than 0.4 per cent of copper.

DETERMINATION OF SILICON.

See the Determination of Silicon in Plain Carbon Steel by the Nitro-Sulfuric Method.[1]

See the Determination of Silicon in Plain Carbon Steel by the Sulfuric Acid Method (Optional).[1]

DETERMINATION OF NICKEL BY THE GRAVIMETRIC DIMETHYLGLYOXIME METHOD.

SOLUTIONS REQUIRED.

Dilute Nitric Acid (*1 : 3*)—Mix 250 cc. of HNO_3 (sp. gr. 1.42) with 750 cc. of distilled water.

Dilute Hydrochloric Acid (*1 : 1*).—Mix 500 cc. of HCl (sp. gr. 1.19) and 500 cc. of distilled water.

Dimethylglyoxime (*1-per-cent*).—Dissolve 20 g. of dimethylglyoxime in 1300 cc. of NH_4OH (sp. gr. 0.90) and dilute to 2000 cc. Ten cubic centimeters of this solution allow sufficient excess to completely precipitate 0.015 g. of nickel.

METHOD.

For ordinary nickel steel take a 1-g. sample; with less than 0.10 or more than 5 per cent nickel, larger or smaller samples may be taken. In the presence of less than 0.5 per cent chromium dissolve the sample in 50 cc. of hot dilute HNO_3 (1 : 3). When chromium is present in amounts greater than 0.5 per cent or under circumstances where chromium carbides are present, dissolve the sample in 60 cc. of dilute

[1] Standard Methods of Chemical Analysis of Plain Carbon Steel (Serial Designation: A 33) of the American Society for Testing Materials, see p. 276.

HCl (1 : 1) with the aid of heat and then oxidize the iron and the carbides by adding HNO_3 (sp. gr. 1.42) drop by drop, until effervescence ceases. Boil to remove the products resulting from the decomposition of the HNO_3 and then cool the solution. Add in succession, with stirring after each addition, 12 g. of citric acid or equivalent solution, 20 cc. of NH_4OH (sp. gr. 0.90), sufficient solution of dimethylglyoxime to precipitate all nickel present and finally enough more NH_4OH to make the solution distinctly ammoniacal. The solution will usually have a volume of 200 to 250 cc. and precipitation is complete immediately if the amount of nickel is over 0.10 per cent. With less nickel or in umpire analyses, digestion for one hour is desirable. Stir the solution thoroughly and filter on an asbestos mat on a 2-in. perforated porcelain plate or a Büchner funnel, avoiding strong suction and taking care that the funnel always remains partly filled with liquid. Thoroughly wash the precipitate with water, discard the filtrate and washings, rinse the funnel stem and then with the mat still in place and with suction off, add 25 cc. of a mixture of 20 cc. of HCl (sp. gr. 1.19) and 5 cc. of HNO_3 (sp. gr. 1.42). After one minute, apply suction till dry, repeat the treatment with 25 cc. of the mixture, drain, and wash thoroughly with water. Transfer the solution to a 400-cc. beaker and evaporate the solution to 100 cc. Filter if necessary and repeat the precipitation of the glyoxime by adding 5 g. citric acid, nearly neutralizing the absolutely clear solution with NH_4OH (sp. gr. 0.90) and then adding dimethylglyoxime and NH_4OH as before. Finally filter on a weighed Gooch crucible, thoroughly wash with hot water, dry at 110 to 120° C. and weigh. The precipitate contains 20.31 per cent of nickel.

Allowable Error.—Percentages of nickel determined by the above method should be accurate to $\pm$ [0.005 + (0.01 $\times$ the percentage of nickel found)].

NOTES.

Direct weighing of the precipitate is desirable when small amounts of nickel are concerned. Large precipitates are more conveniently ignited at red heat to NiO. In this case, care must be taken to prevent sublimation of the undecomposed salt. This may be accomplished by enclosing the wet paper and precipitate in one or two wet ashless papers and slowly igniting so that the papers char before taking fire. In this way the compound is decomposed and ignition may proceed at full red heat.

It is difficult to precipitate nickel and to obtain it free from cobalt. when cobalt is preponderant. Complete precipitation may be obtained by adding sufficient dimethylglyoxime to react with both cobalt and nickel and digesting for a longer period, or by oxidizing the cobalt to the trivalent condition by means of $NaClO_3$ or $(NH_4)_2S_2O_8$ in ammoniacal solution before precipitating with dimethylglyoxime. In either case, the first precipitate should be filtered off, dissolved and reprecipitated.

DETERMINATION OF NICKEL BY THE CYANIDE TITRATION METHOD. (ROUTINE.)

PRELIMINARY TREATMENT

The cyanide titration may be performed in a solution prepared as in (*a*), (*b*), or (*c*) below:

(*a*) *Preliminary Separation with Dimethylglyoxime.* (Presence of chromium, copper, cobalt and small amounts of tungsten.)

Proceed as in the gravimetric method until the dimethylglyoxime precipitate has been dissolved in aqua regia, and then evaporate the solution to 50 cc. or until free from dimethylglyoxime and oxidizing gases. Cool the solution, with ice if desired, neutralize with NH_4OH (sp. gr. 0.90) (rosolic acid is a convenient indicator), add 5 cc. in excess, dilute to 250 cc., and proceed as in the final titration below.

(*b*) *Preliminary Ether Extraction.* (Absence of cobalt and more than 1 per cent tungsten.)

SOLUTIONS REQUIRED.

Dilute Hydrochloric Acid (3 : 2).—Mix 600 cc. of HCl (sp. gr. 1.19) and 400 cc. of distilled water.

Acidulated Hydrogen Sulfide Water.—Add 25 cc. of HCl (sp. gr. 1.19) to 500 cc. of distilled water and saturate with H_2S.

METHOD.

In a 150-cc. beaker dissolve 1 g. of the steel in 20 cc. of the dilute HCl (3 : 2), add about 2 cc. of HNO_3 (sp. gr. 1.42) to oxidize the iron, and boil to expel the oxides of nitrogen. Cool, and transfer the solution into an 8-oz. separatory funnel, rinsing the beaker with small portions of the dilute HCl (3 : 2). Add 50. cc of ether, shake for 5 minutes, let settle for 1 minute, and then draw off the lower clear solution into another 8-oz. separatory funnel. Add 10 cc. of dilute HCl (3 : 2) to the solution in the first separatory funnel, cool, shake thoroughly, allow to settle for 1 minute, and then draw off the lower clear solution into the second separatory funnel. To the combined solutions in the second separatory funnel add 50 cc. of ether, shake for 5 minutes, let settle for 1 minute, and then draw off the clear layer into a 150-cc. beaker. Heat the aqueous solution gently to expel the ether, add 0.2 g. of potassium chlorate, boil until the chlorate is decomposed, dilute to 100 cc. with hot water, make faintly ammoniacal, and boil for 5 minutes. Filter and wash with hot water.

To the filtrate add 10 cc. of HCl (sp. gr. 1.19) heat just sho t of boiling and precipitate the copper with hydrogen sulfide. Filter and wash with acidulated hydrogen sulfide water. Boil the filtrate to expel hydrogen sulfide, neutralize with ammonia as in (*a*), add 5 cc. in excess, dilute to 250 cc. and proceed as in the final titration below.

(*c*) *Direct Titration* (Absence of copper, cobalt, and more than 1 per cent of tungsten).

SOLUTIONS REQUIRED.

Dilute Nitric Acid (sp. gr. 1.20).—Mix 380 cc. of HNO_3 (sp. gr. 1.42) and 620 cc. of distilled water.

Ammonium Persulfate (15-per-cent).—Make up as needed by dissolving 15 g. of the salt in 100 cc. of distilled water.

Dilute Ammonia (1 : 1).—Mix equal volumes of NH_4OH (sp. gr. 0.90) and distilled water.

Sulfuric-Citric Acids.—Dissolve 200 g. of citric acid in a cooled mixture of 100 cc. H_2SO_4 (sp. gr. 1.84) and 900 cc. of distilled water.

METHOD.

Transfer 1 g. of the sample to a 400-cc. beaker, treat with 20 cc. of dilute HNO_3 (sp. gr. 1.20) and heat until the sample is dissolved. Add 8 to 10 cc. of ammonium persulfate solution (15-per-cent) and continue the boiling for five minutes. Cool the solution, add 50 cc. of the sulfuric-citric acid mixture, and then dilute NH_4OH (1 : 1) until the solution is just alkaline to litmus, when an excess of 5 cc. is added. In case a precipitate is formed, use more citric acid. The neutralization of the solution should be made as soon as possible after the addition of the citric acid, as otherwise this may reduce traces of iron. Cool to room temperature, dilute to 250 cc. and proceed as in the final titration below.

NOTE.

If chromium is present in amounts over 1 per cent, dissolve the steel in 20 cc. of dilute H_2SO_4 (1 : 4), oxidize with 5 cc. of HNO_3 (sp. gr. 1.42), boil 5 minutes, cool, add 50 cc. of sulfuric-citric acid mixture and proceed as above.

FINAL TITRATION

SOLUTIONS REQUIRED.

Potassium Iodide (10-per-cent).—Dissolve 10 g. of KI in 100 cc. of distilled water.

Standard Silver Nitrate.—Dissolve 5.7903 g. of $AgNO_3$ in distilled water and dilute to exactly 1000 cc.

Standard Potassium Cyanide.—Dissolve 4.5 g. of KCN in 1000 cc.

of distilled water containing 1 g. of KOH. Standardize this solution against the standard silver nitrate solution as follows: To a 400-cc. beaker add 100 cc. of water, 3 cc. of NH_4OH, 2 cc. of potassium iodide solution (10-per-cent), and finally 30 cc. of silver nitrate solution from a burette. Titrate with the cyanide solution until the solution is perfectly clear, and then add more silver nitrate solution until a faint cloudiness is obtained which can be dispelled by two drops of the cyanide solution. Adjust the cyanide solution so that it is equivalent to the silver nitrate solution and check the theoretical value (0.001 g. nickel) by standardizing, by the procedure chosen, against a steel of known nickel content as determined by the gravimetric dimethylglyoxime method.

METHOD.

Add 2 cc. of potassium iodide solution (10-per-cent) to the solution prepared as in (*a*), (*b*), or (*c*) and then from a burette add 3 cc. of standard silver nitrate solution. Slowly add standard cyanide solution, with constant stirring, until the solution is perfectly clear. Continue the addition of the silver nitrate solution and titration with cyanide solution until the cloudiness of the solution, due to the addition of two drops of the standard silver nitrate, is just expelled by the final addition of two drops of the standard cyanide. Each cubic centimeter excess of standard cyanide solution required over standard silver nitrate solution used in the titration represents 0.1 per cent of nickel.

NOTE.

If cobalt is present, an unsatisfactory end point will be obtained if the titration is carried out as directed after a preliminary separation by methods (*b*) or (*c*). Cobalt may, however, be titrated satisfactorily provided it is first oxidized to the trivalent condition by boiling the ammoniacal solution with $NaClO_3$ prior to the titration with cyanide. In this case, the compound $K_3Co(CN)_5$ is formed and the titration represents the combined effect of nickel and cobalt. (See the Determination of Cobalt in Tungsten Steel by the Cyanide Titration Method (Routine)).[1]

CHROME-NICKEL STEEL.

DETERMINATION OF CARBON.

See the Determination of Carbon in Plain Carbon Steel by the Direct-Combustion Method.[2]

NOTE.

Difficultly combustible high-chromium steel can usually be burned directly if the sample is heated for a few minutes before admitting oxygen. A high temperature (1100° C.) is desirable, and in extreme cases complete combustion can be had by mixing the drillings with low-carbon iron or steel.

[1] See p. 333.

[2] Standard Methods of Chemical Analysis of Plain Carbon Steel (Serial Designation: A 33) of the American Society for Testing Materials, see p. 276.

DETERMINATION OF MANGANESE

BY THE

HYDROLYSIS-BISMUTHATE METHOD.

(ABSENCE OF COBALT.)

SOLUTIONS REQUIRED.

Dilute Sulfuric Acid (1:9).—Pour 100 cc. of H_2SO_4 (sp. gr. 1.84) slowly and with stirring into distilled water, cool, and dilute to 1000 cc.

Sodium Bicarbonate (*8-per-cent*).—Dissolve 80 g. of $NaHCO_3$ in 1000 cc. of distilled water.

Dilute Nitric Acid (*3 : 97*).—Mix 30 cc. of HNO_3 (sp. gr. 1.42) and 970 cc. of distilled water.

Ferrous Sulfate.—See the Determination of Manganese in Plain Carbon Steel by the Bismuthate Method.[1]

Standard Potassium Permanganate.—See the Determination of Manganese in Plain Carbon Steel by the Bismuthate Method.[1]

METHOD.

Dissolve 1.000 g. of the sample contained in a 200-cc. covered Erlenmeyer flask in 20 cc. of dilute H_2SO_4 (1 : 9). When action is complete, dilute to 100 cc. with boiling water. Add from a burette sodium bicarbonate solution (8-per-cent) until a permanent precipitate is formed (approximately 36 cc.) and then 4 cc. more. Boil one minute, allow to settle and filter on a rapid filter, washing 4 to 5 times with boiling water. If the precipitation has been properly performed there will be no more precipitate than can be conveniently handled on a 9-cm. paper. The filtrate will become cloudy in the funnel stem and in the receiving vessel, owing to oxidation and hydrolysis. Heat the filtrate to boiling and oxidize with small portions of HNO_3 (sp. gr. 1.42), adding in all 12 cc. Evaporate to about 25 cc., cool to 15° C., and add an excess of sodium bismuthate. Let stand for a few minutes, add 50 cc. of dilute HNO_3 (3:97), and filter through asbestos. Wash with the same acid until the washings run through colorless. Add 3 cc. of H_3PO_4 (sp. gr. 1.71) and titrate with ferrous sulfate and standard potassium permanganate, as in the Determination of Manganese in Plain Carbon Steel by the Bismuthate Method.[1]

Allowable Error.—Percentages of manganese determined by the above method should be accurate to $\pm$ [0.02 + (0.02 $\times$ the percentage of manganese found)].

[1] Standard Methods of Chemical Analysis of Plain Carbon Steel (Serial Designation: A 33) of the American Society for Testing Materials, see p. 276.

NOTES.

The bicarbonate precipitate does not ordinarily contain more than small amounts (about 0.005 per cent) of manganese. In very accurate work this should be recovered by transferring the precipitate to a beaker, dissolving it in aqua regia, fuming with sulfuric acid, and then adding sodium hydroxide and sodium peroxide and boiling. Chromium and vanadium are thus separated from manganese and iron which should be filtered off, dissolved in 5 cc. of HNO_3 (1 : 1) and added to the filtrate from the bicarbonate precipitation. A drop of sulfurous acid added to the nitric acid aids in the solution of the manganese dioxide.

The determination of maganese by the Ford or Ford-Williams method (preliminary separation of maganese as dioxide by boiling with concentrated nitric acid and potassium chlorate) is satisfactory for steels containing over 0.1 per cent of manganese. This method should not be used, however, except in laboratories which have excellent ventilation facilities.

DETERMINATION OF MANGANESE BY THE PERSULFATE METHOD. (ROUTINE AND IN PRESENCE OF COBALT.)

See the Determination of Manganese in Plain Carbon Steel by the Persulfate Method (Routine).[1]

NOTE.

In making the titration special care should be given to standardizing the end-point reading and the reading should be corrected by a blank, which varies with the amount of chromium present.

DETERMINATION OF PHOSPHORUS.

See the Determination of Phosphorus in Plain Carbon Steel by the Molybdate-Magnesia Method.[1]

See the Determination of Phosphorus in Plain Carbon Steel by the Alkalimetric Method.[1]

DETERMINATION OF SULFUR.

See the Determination of Sulfur in Plain Carbon Steel by the Oxidation Method.[1]

See the Determination of Sulfur in Plain Carbon Steel by the Evolution-Titration Method (Routine).[1]

NOTES.

The Evolution-Titration Method should not be used with steels containing appreciable amounts of tungsten or molybdenum or more than 0.4 per cent of copper.

The annealing of the steel drillings has been found by a number of investigators to increase the degree of refinement of the method.

[1] Standard Methods of Chemical Analysis of Plain Carbon Steel (Serial Designation: A 33) of the American Society for Testing Materials, see p. 276.

DETERMINATION OF SILICON.

(*a*) *Low Chromium.*

See the Determination of Silicon in Plain Carbon Steel by the Nitro-Sulfuric Method.[1]

(*b*) *High Chromium.*

SOLUTIONS REQUIRED.

Dilute Sulfuric Acid (1 : 9).—Pour 100 cc. of H_2SO_4 (sp. gr. 1.84) slowly and with stirring into 900 cc. of distilled water.

Dilute Hydrochloric Acid (5 : 95).—Mix 50 cc. of HCl (sp. gr. 1.19) and 950 cc. of distilled water.

METHOD.

Dissolve 2.338 g. of the sample in a covered porcelain dish in 30 cc. of HCl (sp. gr. 1.19) or 100 cc. of dilute sulfuric acid (1 : 9). If vanadium or molybdenum is present, add a few crystals of sodium chlorate when the action is complete, boil, and then evaporate to low bulk. If sulfuric acid has not been added, cautiously add 15 cc. of H_2SO_4 (sp. gr. 1.84) and continue the evaporation until fumes of H_2SO_4 begin to come off. Do not prolong this treatment or allow the solution to go to dryness lest insoluble chromium and nickel sulfates be formed. Cool, dilute with 125 cc. of distilled water, add 5 cc. of HCl (sp. gr. 1.19) and warm gently with frequent stirring until the soluble salts have dissolved. Immediately filter through an 11-cm. filter paper, wash with dilute HCl (5:95) until free from iron and then with hot water until free from acid. Transfer the filter to a platinum crucible, burn off the paper carefully and finally ignite, with the crucible covered, over a blast lamp or in a muffle furnace at 1000° C. for at least 10 minutes. Cool in a desiccator and weigh. Add sufficient dilute H_2SO_4 (1:1) to moisten the silica, and then a small amount of HF. Evaporate to dryness, ignite and weigh. The difference in weights represents the amount of silica.

NOTE.

A blank determination on all reagents used should be made and the results corrected accordingly.

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[1] Standard Methods of Chemical Analysis of Plain Carbon Steel (Serial Designation: A 33) of the American Society for Testing Materials, see p. 276.

DETERMINATION OF CHROMIUM BY THE PERSULFATE OXIDATION METHOD.

SOLUTIONS REQUIRED.

Sulfuric-Phosphoric Acid Mixture.—Mix 320 cc. of H_2SO_4 (1 : 1), 80 cc. of H_3PO_4 (85-per-cent) and 600 cc. of distilled water.

Dilute Nitric Acid (sp. gr. 1.20).—Mix 380 cc. of HNO_3 (sp. gr. 1.42) and 620 cc. of distilled water.

Silver Nitrate (2.5-per-cent).—Dissolve 25 g. of $AgNO_3$ in 1000 cc. of distilled water.

Ammonium Persulfate (15-per-cent)—Make up as needed by dissolving 15 g. of the salt in 100 cc. of distilled water.

Sodium Chloride (5-per-cent).—Dissolve 50 g. of NaCl in 1000 cc. of distilled water.

Standard Ferrous Sulfate.—Dissolve 12 g. of ferrous ammonium sulfate in a cold mixture of 50 cc. of H_2SO_4 (sp. gr. 1.84) and 950 cc. of distilled water. This solution is preferably adjusted so that it is exactly equivalent to the permanganate solution which is used.

Standard Permanganate Solution.—Dissolve 0.95 g. of $KMnO_4$ in 1000 cc. of distilled water, allow to age for at least one week and filter through purified asbestos. When much work is done, a desirable method of preparing the solution consists in aging large volumes of two solutions, one slightly stronger than the above and one about one-fifth as strong. Clear, one to two-liter portions of these aged solutions may then be siphoned off, standardized and mixed to get the desired titre. Standardize the permanganate solution against the Bureau of Standards Standard Sodium Oxalate Sample No. 40*a* as follows:

In a 200-cc. beaker dissolve 0.075 to 0.10 g. of sodium oxalate in 75 cc. of hot water (80 to 90° C.) and add 5 cc. of dilute H_2SO_4 (1 : 1). Titrate at once with the permanganate solution, stirring the liquid vigorously and continuously. The permanganate must not be added more rapidly than 10 to 15 cc. per minute, and the last 0.5 to 1 cc. must be added dropwise, with particular care to allow each drop to be fully decolorized before the next is introduced. The excess of permanganate used to cause an end point color must be estimated by matching the color in another beaker containing the same bulk of acid and hot water. The temperature of the solution should not be below 60° C. by the time the end point is reached.

METHOD.

Transfer 2 g. of the sample to a 600-cc. beaker and add 60 cc. of sulfuric-phosphoric acid mixture. Heat until all action ceases, add 10 cc. of HNO_3 (sp. gr. 1.20), and boil until solution is complete and oxides of nitrogen are expelled. Add silver nitrate solution (2.5-per-cent) in amount equal to 0.03 g. of the salt for each 1.5 per cent of chromium present. Dilute to 300 cc. with boiling water, heat to boiling, and add 8 cc. of ammonium persulfate solution (15-per-cent). When the permanganate color has developed, add 5 cc. of sodium chloride solution (5-per-cent) and boil until the pink color disappears and the persulfate is decomposed, which requires about 10 minutes. Cool the solution, dilute to approximately 400 cc. and titrate for chromium as follows: Add a measured excess of standard ferrous sulfate solution (50 cc. for less than 1.5 per cent chromium, 100 cc. for 1.5 to 3 per cent chromium) and then titrate with the standard potassium permanganate solution until an end point is obtained which is permanent upon continued stirring for at least one minute. The titration must be corrected for dilution and color effect. If no chromium or nickel were present the dilution effect alone would be involved and satisfactorily eliminated by titrating the same volume of ferrous sulfate solution in a solution of like volume and acidity. In colored solutions the correction can be made (1) empirically, as judged by experience; (2) by titration of the same volume of ferrous sulfate in a solution of like volume and acidity and containing the same amount of the coloring elements in their final valency; or (3) in the final titrated solution. The last is the most convenient and satisfactory and may be performed by destroying the slight excess of permanganate which is present in the titrated solution by a few drops of hydrogen peroxide, boiling until the excess of peroxide and the pervanadate are destroyed (10 minutes actual boiling), cooling to room temperature, and then titrating with the permanganate solution. The difference between the volumes of permanganate used is then a true oxidizing equivalent of the excess of ferrous sulfate employed and the percentage of chromium may be calculated in the usual manner. The final solution may be preserved for the determination of vanadium as described in the Determination of Vanadium in Chrome-Vanadium Steel by Reduction with Ferrous Sulfate and Titration with Permanganate Method (Routine).[1]

Allowable Error.—Percentages of chromium determined by the above method should be accurate to $\pm$ [0.01 + (0.01 $\times$ the percentage of chromium found)].

[1] See p. 317.

DETERMINATION OF NICKEL.

See the Determination of Nickel in Nickel Steel by the Gravimetric Dimethylglyoxime Method.[1]

See the Determination of Nickel in Nickel Steel by the Cyanide Titration Method (Routine).[2]

VANADIUM STEEL.

All determinations are carried out as in the methods of chemical analysis of Chrome-Vanadium Steel.

CHROME–VANADIUM STEEL.

DETERMINATION OF CARBON.

See Determination of Carbon in Chrome-Nickel Steel.[3]

DETERMINATION OF MANGANESE.

See the Determination of Manganese in Chrome-Nickel Steel by the Hydrolysis-Bismuthate Method.[4]

See the Determination of Manganese in Chrome-Nickel Steel by the Persulfate Method (Routine).[5]

DETERMINATION OF PHOSPHORUS BY THE MODIFIED MOLYBDATE-MAGNESIA METHOD.

SOLUTIONS REQUIRED.

Dilute Nitric Acid (sp. gr. 1.20).—Mix 380 cc. of HNO_3 (sp. gr. 1.42) and 620 cc. of distilled water.

Dilute Nitric Acid (2 : 100).—Mix 20 cc. of HNO_3 (sp. gr. 1.42) and 1000 cc. of distilled water.

Potassium Permanganate (2.5-per-cent).—See the Determination of Phosphorus in Plain Carbon Steel by the Molybdate-Magnesia Method.[6]

Ammonium Bisulfite (3-per-cent).—See the Determination of Phosphorus in Plain Carbon Steel by the Molybdate-Magnesia Method.[6]

Ammonium Molybdate.—See the Determination of Phosphorus in Plain Carbon Steel by the Molybdate-Magnesia Method.[6]

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[1] See p. 301. [2] See p. 303. [3] See p. 305. [4] See p. 306. [5] See p. 307.

[6] Standard Methods of Chemical Analysis of Plain Carbon Steel (Serial Designation: A 33) of the American Society for Testing Materials, see p. 276.

Magnesia Mixture.—See the Determination of Phosphorus in Plain Carbon Steel by the Molybdate-Magnesia Method.[1]

Dilute Ammonium Hydroxide (1 : 2).—See the Determination of Phosphorus in Plain Carbon Steel by the Molybdate-Magnesia Method.[1]

Dilute Ammonium Hydroxide (1 : 19).—See the Determination of Phosphorous in Plain Carbon Steel by the Molybdate-Magnesia Method.[1]

Ferrous Sulfate.—Dissolve 40 g. of ferrous sulfate in 100 cc. of distilled water that has been acidified with 1 cc. of H_2SO_4 (sp. gr. 1.84).

METHOD.

In a 300-cc. Erlenmeyer flask dissolve 5 g. of steel in 75 cc. of dilute HNO_3 (sp. gr. 1.20). Heat, and while boiling, add about 12 cc. of potassium permanganate solution (2.5-per-cent), and continue boiling until manganese dioxide precipitates. Dissolve the precipitate by additions of ammonium bisulfite solution (3-per-cent) or ferrous sulfate solution, boil until clear and free from oxides of nitrogen. Cool to 15 to 20° C., add 5 cc. of the ferrous sulfate solution, and 2 or 3 drops of concentrated sulfurous acid, and then 100 cc. of the ammonium-molybdate solution. Shake or agitate thoroughly for 5 minutes, allow to settle for at least 30 minutes, filter on a 9-cm. paper and wash the flask and precipitate at least 3 times with dilute HNO_3 (2 : 100) to free from iron. Treat the precipitate on the filter with dilute NH_4OH (1 : 2), letting the solution run into the original flask and avoiding the use of more than 10 to 20 cc. of the reagent. Pour a solution of 0.5 g. of citric acid in 15 cc. of water and 10 cc. of HCl (sp. gr 1.19) through the filter in order to dissolve any ferric phosphate on the paper and render acid the ammoniacal solution of the phosphate. Transfer the solution to a 100-cc. beaker, add 10 cc. of the magnesia mixture, and precipitate the phosphate by adding ammonium hydroxide (sp. gr. 0.90) slowly and with constant stirring, until a crystallin precipitate is formed or the solution is alkaline. Finally add 10 per cent by volume in excess. Set aside in a cool place for from 2 to 6 hours, filter and wash with dilute NH_4OH (1 : 19). Ignite and weigh. Dissolve the precipitate of magnesium pyrophosphate with 5 cc. of dilute HNO_3 (sp. gr. 1.20) and 20 cc. of water, filter and wash with hot water. Ignite and weigh. The difference in weights represents pure magnesium pyrophosphate containing 27.87 per cent of phosphorus.

[1] Standard Methods of Chemical Analysis of Plain Carbon Steel (Serial Designation: A 33) of the American Society for Testing Materials, see p. 276.

Allowable Error.—Percentages of phosphorus determined by the above method should be accurate to ± [0.003 + (0.02 × the percentage of phosphorus found)].

NOTES.

The ammonium-molybdate solution should be kept in a cool place and should always be absolutely clear before using.

If arsenic is present in the steel, it will come down in part with the phosphomolybdate and contaminate the pyrophosphate. In very accurate work or when arsenic is present in appreciable amount, steps must be taken for its removal before precipitation with magnesia mixture.

DETERMINATION OF PHOSPHORUS BY THE MODIFIED ALKALIMETRIC METHOD. (ROUTINE.)

SOLUTIONS REQUIRED.

Dilute Nitric Acid (sp. gr. 1.20).—See the Determination of Phosphorus by the Modified Molybdate-Magnesia Method.[1]

Dilute Nitric Acid for Washing (2 : 100).—See the Determination of Phosphorus by the Modified Molybdate-Magnesia Method.[1]

Potassium Permanganate (2.5-per-cent).—See the Determination of Phosphorus by the Modified Molybdate-Magnesia Method.[1]

Ammonium Bisulfite (3-per-cent).—See the Determination of Phosphorus by the Modified Molybdate-Magnesia Method.[1]

Ammonium Molybdate.—See the Determination of Phosphorus by the Modified Molybdate-Magnesia Method.[1]

Ferrous Sulfate.—See the Determination of Phosphorus by the Modified Molybdate-Magnesia Method.[1]

Potassium Nitrate (1-per-cent).—See the Determination of Phosphorus in Plain Carbon Steel by the Alkalimetric Method (Routine).[2]

Phenolphthalein Indicator.—See the Determination of Phosphorus in Plain Carbon Steel by the Alkalimetric Method (Routine).[2]

Standard Sodium Hydroxide.—See the Determination of Phosphorus in Plain Carbon Steel by the Alkalimetric Method (Routine).[2]

Standard Nitric Acid.—See the Determination of Phosphorus in Plain Carbon Steel by the Alkalimetric Method (Routine).[2]

METHOD.

In a 300-cc. Erlenmeyer flask, dissolve 2 g. of steel in 50 cc. of dilute HNO_3 (sp. gr. 1.20). Heat, and while boiling add 6 cc. of

[1] See p. 311.

[2] Standard Methods of Chemical Analysis of Plain Carbon Steel (Serial Designation: A 33) of the American Society for Testing Materials, see p. 276.

potassium permanganate solution (2.5-per-cent) and continue boiling until manganese dioxide precipitates. Dissolve this precipitate by additions of the ammonium bisulfite solution (3-per-cent) or ferrous sulfate solution, boil until clear and free from oxides of nitrogen and cool to 15 to 20° C. Add 5 cc. of the ferrous sulfate solution and 2 or 3 drops of concentrated sulfurous acid, and then 50 cc. of the ammonium-molybdate solution. Shake or agitate for 5 minutes, allow to settle for at least 30 minutes, filter on a 9-cm. paper, wash the precipitate and flask three times with dilute HNO_3 (2 : 100) to free it from iron, and continue the washing with the potassium nitrate solution (1-per-cent) until the precipitate and flash are free from acid.

Transfer the paper and precipitate to the solution flask, add 20 cc. of distilled water (see Notes), 5 drops of phenolphthalein solution as indicator, and an excess of the standard sodium hydroxide solution. Insert a rubber stopper and shake vigorously until solution of the precipitate is complete. Wash off the stopper with distilled water and determine the excess of standard sodium hydroxide solution by titrating with standard nitric acid solution. Each cubic centimeter of standard sodium hydroxide solution represents 0.01 per cent of phosphorus.

NOTES.

The ammonium molybdate solution should be kept in a cool place and should always be absolutely clear before using.

All distilled water used in titration should be freed from carbon dioxide by boiling or otherwise.

Bureau of Standards Standard Steel No. 30*b* or its renewal is recommended as a suitable steel for standardizing the sodium hydroxide solution.

DETERMINATION OF SULFUR.

See the Determination of Sulfur in Plain Carbon Steel by the Oxidation Method.[1]

See the Determination of Sulfur in Plain Carbon Steel by the Evolution-Titration Method (Routine).[1]

NOTES.

The Evolution-Titration Method should not be used with steels containing appreciable amounts of tungsten or molybdenum or more than 0.4 per cent of copper.

The annealing of the steel drillings has been found by a number of investigators to increase the degree of refinement of the method.

[1] Standard Methods of Chemical Analysis of Plain Carbon Steel (Serial Designation: A 33) of the American Society for Testing Materials, see p. 276.

DETERMINATION OF SILICON.

See the Determination of Silicon in Plain Carbon Steel by the Nitro-Sulfuric Method.[1]

See the Determination of Silicon in Plain Carbon Steel by the Sulfuric-Acid Method (Optional).[1]

DETERMINATION OF CHROMIUM.

See the Determination of Chromium in Chrome-Nickel Steel by the Persulfate Oxidation Method.[2] Reserve the titrated solution for the Determination of Vanadium by Reduction with Ferrous Sulfate and Titration with Permanganate (Routine).[3]

DETERMINATION OF VANADIUM BY THE ELECTROLYTIC SEPARATION METHOD.

SOLUTIONS REQUIRED.

Dilute Sulfuric Acid (1 : 9).—Carefully mix 100 c.c of H_2SO_4 (sp. gr. 1.84) and 900 cc. of distilled water.

Dilute Sulfuric Acid (1 : 1).—Add 500 cc. of H_2SO_4 (sp. gr. 1.84) slowly and with stirring to 500 cc. of distilled water.

Sodium Bicarbonate (8-per-cent).—Dissolve 80 g. of $NaHCO_3$ in 1000 cc. of distilled water.

Potassium Ferricyanide.—Prepare a very dilute solution as needed, by dissolving a crystal the size of the head of a pin in 25 cc. of distilled water.

Standard Potassium Permanganate.—See the Determination of Chromium in Chrome-Nickel Steel by the Persulfate Oxidation Method.[2]

METHOD.

Dissolve 2 g. of the sample, contained in a 200-cc. covered Erlenmeyer flask, in 30 cc. of dilute H_2SO_4 (1 : 9). When action is complete, dilute to 100 cc. with boiling water, heat to boiling, and add sodium bicarbonate solution (8-per-cent) from a burette until a permanent precipitate appears (approximately 36 cc.) and then 4 cc. more. Let settle, filter on a rapid filter and quickly wash the flask and precipitate with hot water. If the precipitation has been properly performed there will be no more precipitate than can be conveniently

[1] Standard Methods of Chemical Analysis of Plain Carbon Steel (Serial Designation: A 33) of the American Society for Testing Materials, see p. 276.

[2] See p. 309. [3] See p. 317.

handled on a 9-cm. paper. The filtrate will become cloudy in the funnel stem and in the receiving vessel, owing to oxidation and hydrolysis. (If the flask, paper and precipitate have been well washed, the filtrate will contain all but traces of the manganese in the sample free from chromium and vanadium, and therefore, it may be oxidized with nitric acid and the manganese determined by the bismuthate or persulfate methods.) Place the paper and precipitate in the original flask, add 20 cc. of HNO_3 (sp. gr. 1.42) shake until the paper is broken up, and then add 5 cc. of H_2SO_4 (sp. gr. 1.84). Heat over a free flame until fumes of sulfuric acid are given off, cool, and then add more HNO_3 and repeat the heating in case the organic matter has not been destroyed. Finally cool, wash down the sides of the flask, and evaporate again to the appearance of fumes of sulfuric acid and until all of the nitric acid has been expelled. Cool, dilute to 40 cc. and nearly neutralize the solution with NH_4OH (sp. gr. 0.90). Transfer the weakly acid solution to the electrolyzing apparatus, rinsing the flask with small portions of water and keeping the total volume of the solution down to 70 cc. The electrolysis may be performed with a mercury cathode in (1) a special modified separatory funnel,[1] (2) in a small beaker with sealed-in platinum wire,[2] or (3) in an ordinary beaker with the cathode wire enclosed in a glass tube extending into the mercury. In any case, the cathode wire should be imbedded in about 200 g. of mercury, and the solution electrolyzed (preferably with a stirring arrangement) using a current of 5 to 6 amperes at 6 to 7 volts. Continue the electrolysis (ordinarily 15 to 20 minutes if the solution is stirred) until iron is absent as indicated by a ferricyanide test on a small drop of the electrolyte. When iron is absent, remove the electrolyte and wash the mercury two or three times with 25 to 30 cc. of water while the current is continued. The solution must now give no test for iron. Add 2 to 3 cc. of dilute H_2SO_4 (1 : 1), heat to 70 to 80° C., and add permanganate solution to a strong pink color. Run sulfur dioxide into the boiling solution for a few minutes until the vanadium is reduced, and then a rapid stream of carbon dioxide until the escaping steam gives no test for SO_2. Cool the solution to 70 to 80° C. and titrate with the standard permanganate solution. Repeat the reduction and titration until concordant results are obtained. The titration should be corrected by a blank determination on a solution of like volume and acidity.

Allowable Error.—Percentages of vanadium determined by the above method should be accurate to $\pm$ [0.02 + (0.01 $\times$ the percentage of vanadium found)].

[1] Reprint 161 from the *Bulletin* of the Bureau of Standards, Vol. 7, No. 3; *Journal Industrial and Engineering Chemistry*, Vol. 3, p. 476 (1911).

[2] Smith, Electroanalysis, Fifth Edition, P. Blakiston's Son and Co., p. 63.

DETERMINATION OF VANADIUM BY REDUCTION WITH FERROUS SULFATE AND TITRATION WITH PERMANGANATE.

(ROUTINE.)

SOLUTIONS REQUIRED.

Sulfuric-Phosphoric Acid Mixture.—See the Determination of Chromium in Chrome-Nickel Steel by the Persulfate Oxidation Method.[1]

Dilute Nitric Acid (1 : 1).—See the Determination of Chromium in Chrome-Nickel Steel by the Persulfate Oxidation Method.[1]

Silver Nitrate (2.5-per-cent).—See the Determination of Chromium in Chrome-Nickel Steel by the Persulfate Oxidation Method.[1]

Ammonium Persulfate (15-per-cent).—See the Determination of Chromium in Chrome-Nickel Steel by the Persulfate Oxidation Method.[1]

Sodium Chloride (5-per-cent).—See the Determination of Chromium in Chrome-Nickel Steel by the Persulfate Oxidation Method.[1]

Standard Ferrous Sulfate.—See the Determination of Chromium in Chrome-Nickel Steel by the Persulfate Oxidation Method.[1]

Standard Potassium Permanganate.—See the Determination of Chromium in Chrome-Nickel Steel by the Persulfate Oxidation Method.[1]

METHOD.

See the Determination of Chromium in Chrome-Nickel Steel by the Persulfate Oxidation Method.[1]

Use the solution employed for the determination of chromium and add 10 cc. of ferrous sulfate solution if vanadium is under 0.80 per cent, and 20 cc. if the vanadium content is higher. Stir the solution thoroughly, add 8 cc. of ammonium persulfate solution (15-per-cent) and stir for one minute. Titrate with the standard permanganate solution to a definite pink color which does not fade upon continued stirring for one minute. In this determination the ferrous sulfate reduces the vanadium, the persulfate oxidizes the excess of ferrous sulfate but does not oxidize the reduced vanadium and the reduced vanadium is oxidized by permanganate which does not react with the excess of persulfate. As in the determination of chromium, an excess of permanganate is used in order to overcome the dilution effect and the color interference, and the same blank correction should be subtracted as was there found.

[1]See p. 309.

TUNGSTEN STEEL.

DETERMINATION OF CARBON.

See the Determination of Carbon in Plain Carbon Steel by the Direct-Combustion Method.[1]

NOTE.

Difficultly combustible tungsten steel can often be burned directly if the sample is heated for a few minutes before admitting oxygen. A high temperature (1100° C.) is desirable, and in extreme cases complete combustion can be had by mixing the sample with low-carbon iron or steel.

DETERMINATION OF MANGANESE BY THE HYDROLYSIS-BISMUTHATE METHOD.

(ABSENCE OF COBALT.)

See the Determination of Manganese in Chrome-Nickel Steel by the Hydrolysis-Bismuthate Method.[2]

NOTES.

The retention of manganese by the bicarbonate precipitate is a little greater in steels containing tungsten than in steels containing no tungsten, but the retention is usually no more than from 0.01 to 0.02 per cent. In very accurate work this should be recovered as follows:

Place the paper and precipitate in the original flask, add 20 cc. of HNO_3 (sp. gr. 1.42) shake until the paper is broken up, and then add 5 cc. of H_2SO_4 (sp. gr. 1.84). Heat over a free flame until fumes of sulfuric acid are given off, cool, and then add more HNO_3 and repeat the heating in case the organic matter has not been destroyed. Finally cool, wash down the sides of the flask, and evaporate again to the appearance of fumes of sulfuric acid and until all of the nitric acid has been expelled. Cool, dilute, neutralize with sodium hydroxide, then add sodium peroxide and boil. Chromium, vanadium, and tungsten are thus separated from manganese and iron, which should be filtered off, and washed with hot water containing a little sodium hydroxide. Dissolve the precipitate of iron and maganese in warm dilute 1:1 nitric acid with the aid of a few drops of sulfurous acid if necessary, and add the solution to the original filtrate.

Cobalt interferes in the above method. When this element is present the persulfate method must be used with a fresh sample as directed below, or in the filtrate obtained after the bicarbonate precipitation. In the latter event, acidify the filtrate with nitric acid, add 10 cc. of dilute sulfuric acid (1:1) and evaporate to a volume of 20 cc. Add 10 cc. of HNO_3 (sp. gr. 1.20) and proceed as directed below. With material containing much cobalt use one-fourth of the solution, which will represent 0.5 g. of steel.

Allowable Error.—Percentages of manganese determined by the above method should be accurate to $\pm$ [0.02 + (0.02 $\times$ the percentage of manganese found)].

[1] Standard Methods of Chemical Analysis of Plain Carbon Steel (Serial Designation: A 33) of the American Society for Testing Materials, see p. 276.

[2] See p. 306.

DETERMINATION OF MANGANESE BY THE PERSULFATE-ARSENITE METHOD.

(ROUTINE AND IN THE PRESENCE OF COBALT.)

SOLUTIONS REQUIRED.

Dilute Sulfuric Acid (1 : 1).—Pour 500 cc. of H_2SO_4 (sp. gr. 1.84) slowly and with constant stirring, into 500 cc. of distilled water.

Dilute Nitric Acid (sp. gr. 1.20).—Mix 380 cc. of HNO_3 (sp. gr. 1.42) and 620 cc. of distilled water.

Silver Nitrate (0.5-per-cent).—Dissolve 5 g. of $AgNO_3$ in a mixture of 750 cc. of distilled water with 250 cc. of H_2SO_4 (1 : 1).

Ammonium Persulfate (15-per-cent).—Prepare as needed by dissolving 15 g. of $(NH_4)_2S_2O_8$ in 100 cc. of distilled water.

Sodium Chloride (0.5-per-cent).—Dissolve 5 g. of NaCl in 1000 cc. of distilled water.

Standard Sodium Arsenite Solution.—Dissolve 2 g. of sodium arsenite in 1000 cc. of distilled water and standardize against a standard steel or by withdrawing 10 cc. of 0.03 *N* permanganate (or its equivalent) into a 250-cc. beaker, reducing with a few drops of sulfurous acid and then proceeding as described in the method below.

METHOD.

Transfer 0.50 g. of steel to a flask, add 25 cc. of water, 5 cc. of dilute H_2SO_4 (1 : 1) and 2 cc. of phosphoric acid (85-per-cent) and heat until all effervescence ceases. Add 10 cc. of HNO_3 (sp. gr. 1.20), and boil to dissolve the tungstic acid. Add 50 cc. of silver nitrate solution (0.5-per-cent) (sufficient for 5 per cent chromium steel), boil, and add 15 cc. of ammonium persulfate solution (15-per-cent). Remove the flask from the heat, allow to stand in a warm place until the color has developed, and then rapidly cool. Transfer the solution to a 250-cc. beaker, dilute to a volume of 100 cc. and add 30 cc. of sodium chloride solution (0.5-per-cent) to precipitate the silver. Titrate with the standard sodium arsenite solution to the disappearance of the pink tint of permanganic acid. The addition of sodium chloride is unnecessary if the solution of permanganic acid is quite cold and the titration is conducted rapidly.

DETERMINATION OF PHOSPHORUS BY THE MOLYBDATE-MAGNESIA METHOD.

SOLUTIONS REQUIRED.

Dilute Hydrochloric Acid (1 : 1).—Dilute 500 cc. of HCl (sp. gr. 1.19) with 500 cc. of distilled water.

Dilute Hydrochloric Acid (1 : 10).—Dilute 100 cc. of HCl (sp. gr. 1.19) with 1000 cc. of distilled water.

Ferrous Sulfate.—Dissolve 40 g. of ferrous sulfate in 100 cc. of water and acidify with 1 cc. of H_2SO_4 (sp. gr. 1.84).

Ammonium Molybdate.—See the Determination of Phosphorus in Plain Carbon Steel by the Molybdate-Magnesia Method.[1]

Dilute Nitric Acid for Washing (2 : 100).—See the Determination of Phosphorus in Plain Carbon Steel by the Molybdate-Magnesia Method.[1]

Dilute Ammonium Hydroxide (1 : 2).—See the Determination of Phosphorus in Plain Carbon Steel by the Molybdate-Magnesia Method.[1]

Magnesia Mixture.—See the Determination of Phosphorus in Plain Carbon Steel by the Molybdate-Magnesia Method.[1]

METHOD.

Treat 2 g. of the sample, in a porcelain dish provided with a cover glass, with 20 cc. of HNO_3 (sp. gr. 1.42) and 60 cc. of HCl (sp. gr. 1.19). Heat gently until the sample is completely decomposed and then evaporate to dryness. Remove the cover glass and bake until the acid is completely expelled. Cool, add 30 cc. of HCl (sp. gr. 1.19), warm until the soluble salts are dissolved and then evaporate to dryness on the sand-bath. Add 30 cc. of dilute HCl (1 : 1) and boil the solution until the soluble salts are dissolved. Dilute to 60 cc. with boiling water, filter from the silica and tungstic acid, and wash the residue with dilute HCl (1:10) until free from iron. (See Note.) Evaporate the filtrate to approximately 20 cc., cool, and make ammoniacal. Dissolve the precipitated hydroxides in the exact amount of HNO_3 (sp. gr. 1.42) necessary to effect complete solution and add 5 cc. in excess. The further treatment depends on whether vanadium is absent or present. If vanadium is absent, proceed as in the Determination of Phosphorus in Plain Carbon Steel by the Molybdate-Mag-

[1] Standard Methods of Chemical Analysis of Plain Carbon Steel (Serial Designation: A 33) of the American Society for Testing Materials, see p. 276.

nesia Method;[1] if vanadium is present, proceed as in the Determination of Phosphorus in Chrome-Vanadium Steel by the Modified Molybdate-Magnesia Method.[2]

Allowable Error.—Percentages of phosphorus determined by the above method should be accurate to ± [0.004 + (0.02 × the percentage of phosphorus found)].

NOTE.

The residue of tungstic and silicic acids sometimes contains very small amounts of phosphorus and in accurate analyses it must be treated as follows: Ignite in a platinum crucible, fuse with a little Na_2CO_3 (free from phosphorus) and dissolve the cooled melt in hot water. Acidify the solution slightly with HCl, add a few crystals of $FeCl_3$, and precipitate with NH_4OH in slight excess. Filter, wash with a hot wash-solution containing a little NH_4OH and NH_4Cl and discard the filtrate. Dissolve the precipitate of ferric hydroxide and ferric phosphate in a small amount of HCl and add to the main filtrate.

DETERMINATION OF PHOSPHORUS BY THE ALKALIMETRIC METHOD. (ROUTINE.)

SOLUTIONS REQUIRED.

Dilute Nitric Acid (1:3).—Dilute 250 cc. of HNO_3 (sp. gr. 142) with 750 cc. of distilled water.

Dilute Hydrochloric Acid (1:1).—Dilute 500 cc. of HCl (sp. gr. 1.19) with 500 cc. of distilled water.

Dilute Hydrochloric Acid (1:10).—Dilute 100 cc. of HCl (sp. gr. 1.19) with 1000 cc. of distilled water.

Ferrous Sulfate.—Dissolve 40 g. of ferrous sulfate in 100 cc. of water and acidity with 1 cc. of H_2SO_4 (sp. gr. 1.84).

Ammonium Molybdate.—See the Determination of Phosphorus in Plain Carbon Steel by the Alkalimetric Method (Routine).[1]

Dilute Nitric Acid for Washing (2 : 100).—See the Determination of Phosphorus in Plain Carbon Steel by the Alkalimetric Method (Routine).[1]

Potassium Nitrate (1-per-cent).—See the Determination of Phosphorus in Plain Carbon Steel by the Alkalimetric Method (Routine).[1]

Phenolphthalein Indicator.—See the Determination of Phosphorus in Plain Carbon Steel by the Alkalimetric Method (Routine).[1]

[1] Standard Methods of Chemical Analysis of Plain Carbon Steel (Serial Designation: A 33) of the American Society for Testing Materials, see p. 276.

[2] See p. 311.

Standard Sodium Hydroxide.—See the Determination of Phosphorus in Plain Carbon Steel by the Alkalimetric Method (Routine).[1]

Standard Nitric Acid.—See the Determination of Phosphorus in Plain Carbon Steel by the Alkalimetric Method (Routine).[1]

METHOD.

Treat 2 g. of the sample, in a porcelain dish provided with a cover glass, with 50 cc. of dilute HNO_3 (1 : 3), add 10 cc. of HCl (sp. gr. 1.19) and evaporate to dryness. Dissolve the soluble salts in 30 cc. of dilute HCl (1 : 1) by boiling, dilute to 60 cc. with water, filter and wash the residue with dilute HCl (1 : 10). Evaporate the filtrate to approximately 100 cc., make the solution ammoniacal, add just enough HNO_3 (sp. gr. 1.42) to effect complete solution and then add 5 cc. in excess. The further treatment depends on whether vanadium is absent or present. If vanadium is absent, proceed as in the Determination of Phosphorus in Plain Carbon Steel by the Alkalimetric Method (Routine).[1] If vanadium is present, proceed as in the Determination of Phosphorus in Chrome-Vanadium Steel by the Modified Alkalimetric Method (Routine).[2]

DETERMINATION OF SULFUR
BY THE
GRAVIMETRIC METHOD.

SOLUTIONS REQUIRED.

Dilute Hydrochloric Acid (1 : 10).—Dilute 100 cc. of HCl (sp. gr. 1.19) with 1000 cc. of distilled water.

Dilute Hydrochloric Acid (1 : 1).—Dilute 500 cc. of HCl (sp. gr. 1.19) with 500 cc. of distilled water.

Cinchonine.—See the Determination of Tungsten by the Acid Digestion-Cinchonine Method.[3]

Cinchonine Wash Solution.—See the Determination of Tungsten by the Acid Digestion-Cinchonine Method.[3]

METHOD.

Treat 5 g. of the sample, in a 600-cc. beaker or Erlenmeyer flask, with 75 cc. of HNO_3 (sp. gr. 1.42) and heat gently. Certain steels react violently. In this event, do not heat but cool the vessel in cold water in order to prevent loss of incompletely oxidized sulfur. Some

[1] Standard Methods of Chemical Analysis of Plain Carbon Steel (Serial Designation: A 33) of the American Society for Testing Materials, see p. 276.

[2] See p. 313.

[3] See p. 324.

steels dissolve very slowly. In this case add 5 cc. of HCl (sp. gr. 1.19) in successive portions as the solution is digested on a steam-bath. When the steel is dissolved, digest until the residue is bright yellow with no dark material, adding fresh portions of acid if necessary. Evaporate the solution to small volume, cool, add 30 cc. of HCl (sp. gr. 1.19), again evaporate to small volume and dilute with boiling water. Boil until soluble salts are in solution, filter and wash the precipitate with dilute HCl (1 : 10), catching the filtrate and washings in a 600-cc. casserole. Evaporate the solution to dryness, add 40 cc. of HCl (sp. gr. 1.19) and again evaporate to dryness and heat for ten minutes at a temperature not to exceed 130° C. Treat the residue with 60 cc. of dilute HCl (1 : 1), warm until soluble salts are in solution, dilute with 50 cc. of boiling water and add 10 cc. of cinchonine solution. After standing in a warm place for several hours, preferably overnight, filter, and wash with cinchonine wash solution. Evaporate the filtrate and washings until a slight film begins to form upon the surface of the solution and proceed as in the Determination of Sulfur in Plain Carbon Steel by the Oxidation Method.[1] The results should be corrected by blanks on reagents carried through all of the steps of the process, paying particular attention to sulfur derived from the cinchonine solution.

Allowable Error.—Percentages of sulfur determined by the above method should be accurate to ± [0.004 + (0.02 × the percentage of sulfur found)].

DETERMINATION OF SILICON

BY

ACID ATTACK AND BAKING AT 120° C.

SOLUTIONS REQUIRED.

Dilute Hydrochloric Acid (1 : 10).—Pour 100 cc. of HCl (sp. gr. 1.19) into 1000 cc. of distilled water.

Dilute Hydrochloric Acid (1 : 1).—Pour 500 cc. of HCl (sp. gr. 1.19) into 500 cc. of distilled water.

Dilute Hydrochloric Acid (5 : 95).—Pour 50 cc. of HCl (sp. gr. 1.19) into 950 cc. of distilled water.

Dilute Sulfuric Acid (1 : 1).—Cautiously pour, with constant stirring, 500 cc. of H_2SO_4 (sp. gr. 1.84) into 500 cc. of distilled water.

Sodium Hydroxide (2 N).—Dissolve 80 g. of NaOH in 1000 cc. of distilled water.

[1] Standard Methods of Chemical Analysis of Plain Carbon Steel (Serial Designation: A 33) of the American Society for Testing Materials, see p. 276.

METHOD.

Treat 2 g. of the sample in a covered beaker with 50 cc. of HCl (sp. gr. 1.19) heat to incipient boiling and then when solution is complete add HNO_3 (sp. gr. 1.42) at intervals and a few drops at a time until the vigorous action which ensues ceases. Digest until the tungstic acid is bright yellow. Add 100 cc. of boiling water, boil for one minute, cool somewhat and filter. Wash the residue thoroughly with dilute HCl (1 : 10) and set the precipitate aside. Evaporate the filtrate to dryness and bake for one hour at a temperature of 120° C. Take up in 15 cc. of HCl (sp. gr. 1.19) and bake again. Take up in 10 cc. of dilute HCl (1 : 1) and 50 cc. of hot water. Filter and wash with dilute HCl (5 : 95). Reserve the filtrate. Ignite the two residues and filter papers in an open deep-form platinum crucible at a temperature high enough to dehydrate the silica and weigh. Treat the residue with a few drops of dilute H_2SO_4 (1 : 1), a few cubic centimeters of hydrofluoric acid and carefully evaporate to dryness. Ignite very cautiously (to avoid spattering) at a temperature not above 800° C. and weigh. The loss in weight is the weight of silica which multiplied by 0.4676 gives the weight of silicon.

Dissolve the ignited tungstic oxide in a slight excess of NaOH solution (2 *N*), boil, and filter off any residue. Wash the residue with hot water, dissolve it in a few cubic centimeters of hot dilute HCl (1 : 1), add the solution to the reserved filtrate and preserve the combined solutions for the Determination of Cobalt.[1]

Allowable Error.—Percentages of silicon determined by the above method should be accurate to $\pm$ [0.02 + (0.02 $\times$ the percentage of silicon found)].

DETERMINATION OF TUNGSTEN BY THE ACID DIGESTION-CINCHONINE METHOD.

SOLUTIONS REQUIRED.

Cinchonine.—Dissolve 125 g. of cinchonine in a mixture of 500 cc. of HCl (sp. gr. 1.19) and 500 cc. of distilled water.

Cinchonine Wash Solution.—Dilute 30 cc. of the above solution to one liter.

Ammonia-Ammonium Chloride.—Pour 200 cc. of NH_4OH (sp. gr. 0.90) into 790 cc. of water and add 10 cc. of HCl (sp. gr. 1.19).

Dilute Hydrochloric Acid (1 : 1).—Pour 500 cc. of HCl (sp. gr. 1.19) into 500 cc. of distilled water.

[1] See p. 330.

METHOD.

Treat 2 g. of the sample in a covered beaker with 50 cc. of HCl (sp. gr. 1.19), heat to incipient boiling and then when solution is complete, add HNO_3 (sp. gr. 1.42) at intervals and a few drops at a time until the vigorous action which ensues ceases. Digest until the tungstic acid is bright yellow. Dilute to 150 cc., add 10 cc. of cinchonine solution, and digest at a temperature of about 90 to 95° C. for thirty minutes or longer, with occasional stirring. Decant the clear solution on a paper, and wash the beaker and the precipitate by decantation four times with 30 to 40-cc. portions of the hot cinchonine wash solution, keeping as much of the precipitate as possible in the beaker. Place the beaker and precipitate under the funnel, and dissolve the precipitate on the paper in the least possible amount of the ammonia-ammonium chloride solution. Wash the paper several times with hot water, once with hot dilute HCl (1 : 1), several more times with hot water, and finally with small portions of the ammonia-ammonium chloride wash. Reserve the paper. Warm the filtrate and add just enough NH_4OH (sp. gr. 0.90) to dissolve the tungstic acid. Evaporate the solution until most of the ammonia has been expelled and then filter through the reserved paper into a 400-cc. beaker. Wash the original beaker and the paper with small portions of hot water. Reserve the filtrate. The residue may contain a little tungsten, therefore treat it with successive small portions of hot dilute HCl (1 : 1), hot water, and ammonia-ammonium chloride solution. Render this solution slightly alkaline, boil to expel most of the ammonia, filter through the original paper and wash with a little hot water. Combine the ammoniacal filtrates. (The above treatments serve to remove any tantalum or columbium as well as iron and chromium and render unnecessary any purification of the final hydrofluoric acid-treated tungstic oxide.) Dilute the faintly ammoniacal filtrates to 200 cc., add 10 cc. of HCl (sp. gr. 1.19) and boil for ten minutes. Add 10 cc. of cinchonine solution and digest in a warm place for 15 to 30 minutes with occasional stirring. Add a little paper pulp, filter, and wash the precipitate with hot cinchonine wash solution. Add 5 cc. of cinchonine to the filtrate and washings, set aside in a warm place for several hours, and in case any tungstic acid settles out, filter it off, wash and add to the main precipitate. Ignite the tungstic acid under oxidizing conditions in a deep-form platinum crucible until the carbon is destroyed and finally at 800 to 900° C. Cool the crucible and contents, moisten the oxide with hydrofluoric acid, carefully evaporate to dryness and then cautiously (to avoid

spattering) ignite as before and weigh as WO_3. Multiply by 0.7931 to obtain the weight of tungsten.

Allowable Error.—Percentages of tungsten determined by the above method should be accurate to $\pm$ [0.05 + (0.01 $\times$ the percentage of tungsten found)].

NOTES.

1. Tungstic acid is incompletely precipitated by acid digestion alone of solutions containing appreciable amounts of alkali or ammonium salts, phosphorus, or molybdenum, and only slowly by cinchonine in such solutions.

2. Tungstic acid carries down phosphorus pentoxide if it is present in appreciable amount. The small amount present in the solution of the steel is not carried down in sufficient amount to affect the determination of tungsten.

3. Molybdenum is carried down by tungstic acid and must be recovered from the final weighed oxide as specified under the Determination of Molybdenum in Molybdenum Steel by Precipitation as Sulfide and Weighing as Lead Molybdate ((*b*) Presence of Tungsten)[1] and deducted as MoO_3.

DETERMINATION OF TUNGSTEN AND SILICON BY DIGESTION WITH ACIDS. (ROUTINE.)

METHOD.

(*a*) *Determination of Silicon.*

Proceed exactly as in the Determination of Silicon above until the ignition of the tungstic and silicic acids. Then ignite in a weighed deep-form platinum crucible at a temperature of from 800 to 900° C. and under oxidizing conditions. Weigh, treat the residue with a few drops of dilute H_2SO_4 (1 : 1), and a few cubic centimeters of hydrofluoric acid, and carefully evaporate to dryness. Ignite very cautiously (to avoid spattering) at a temperature not above 800 to 900° C. and again weigh. The loss of weight represents silica which multiplied by 0.4676 gives silicon.

(*b*) *Determination of Tungsten.*

The weight of the residue left after the above treatment represents impure tungstic oxide. To correct for the impurities, cover the residue with about twice its weight of pure dry sodium carbonate and heat until thoroughly fused. Extract the cooled melt with hot water, filter, and wash the residue thoroughly with hot water. Ignite the residue in the original crucible, weigh, subtract the weight from the weight of the crucible and impure tungstic oxide, and multiply the corrected weight of WO_3 by 0.7931 to obtain tungsten.

[1] See p. 335.

DETERMINATION OF CHROMIUM BY THE PERSULFATE OXIDATION METHOD.

See the Determination of Chromium in Chrome-Nickel Steel by the Persulfate Oxidation Method.[1]

Allowable Error.—Percentages of chromium determined by the above method should be accurate to ± [0.01 + (0.02 × the percentage of chromium found)].

DETERMINATION OF VANADIUM BY THE ELECTROLYTIC SEPARATION METHOD.

See the Determination of Vanadium in Chrome-Vanadium Steel by the Electrolytic Separation Method.[2] Proceed exactly as in this method until the bicarbonate precipitate and paper have been dissolved in sulfuric and nitric acids and all of the nitric acid has been expelled. Cool the solution, dilute with three times as much water as there is sulfuric acid present, warm to dissolve the soluble salts and filter through a small filter to remove the tungstic acid. Wash the paper and precipitate with small portions of dilute H_2SO_4 (1:3). Nearly neutralize the filtrate with NH_4OH (sp. gr. 0.90), evaporate, if necessary, to a volume of approximately 70 cc. and proceed with the electrolysis of the weakly acid solution and the determination of vanadium as in the Determination of Vanadium in Chrome-Vanadium Steel by the Electrolytic Separation Method.[2]

Allowable Error.—Percentages of vanadium determined by the above method should be accurate to ± [0.03 + (0.01 × the percentage of vanadium found)].

DETERMINATION OF VANADIUM BY REDUCTION WITH FERROUS SULFATE AND TITRATION WITH PERMANGANATE. (ROUTINE.)

SOLUTIONS REQUIRED.

Dilute Hydrochloric Acid (2:1).—Mix two parts of HCl (sp. gr. 1.19) with one part of water.

[1] See p. 309.
[2] See p. 315.

Dilute Nitric Acid (sp. gr. 1.20).—Mix 380 cc. of HNO_3 (sp. gr. 1.42) and 620 cc. of distilled water.

Dilute Hydrochloric Acid (1:9).—Mix 100 cc. of HCl (sp. gr. 1.19) and 900 cc. of distilled water.

METHOD.

(*a*) (When Cobalt does not exceed 1 per cent.)

Treat 2 g. of the steel in a porcelain dish with 70 cc. of dilute HCl (2:1) and heat until all action ceases. Cautiously add 10 cc. of dilute HNO_3 (sp. gr. 1.20) and evaporate the solution to dryness or to low bulk. Treat the residue with 45 cc. of dilute HCl (2:1) and heat until the soluble portion dissolves. Add an equal volume of water, boil for three minutes, filter and wash the residue thoroughly with dilute HCl (1:9) until free from iron. Evaporate the solution to small volume and destroy hydrochloric acid by small additions of nitric acid (sp. gr. 1.42) followed by boiling. If a residue appears, filter the solution. From this point proceed for chromium as in the Determination of Chromium in Chrome-Nickel Steel by the Persulfate Oxidation Method[1] and for vanadium as in the Determination of Vanadium in Chrome-Vanadium Steel by Reduction with Ferrous Sulfate and Titration with Permanganate Method (Routine).[2]

(*b*) (When Cobalt exceeds 1 per cent.)

See the Determination of Vanadium in Chrome-Vanadium Steel by the Electrolytic Separation Method.[3]

Proceed as described in this method until the bicarbonate precipitate has been washed with hot water. Return the paper and precipitate to the flask and add 60 cc. of dilute HCl (2:1). Heat the solution, add 10 cc. of HNO_3 (sp. gr. 1.20) and evaporate the solution to dryness or to a small volume. Treat the residue with 45 cc. of dilute HCl (2:1) and proceed as described above.

NOTES.

Tungsten interferes with the determination of vanadium by the above method and must be removed. While chromium can be determined in the presence of tungsten, it is conveniently determined in the same sample as is vanadium and the end point is easier to get when tungsten has been removed.

In case hydrochloric acid is present when silver nitrate is added, enough of the latter must be added to take care of this before the regular addition is made.

The pink color of cobalt interferes with the end point readings. If under 1 per cent, the color does not seriously affect the results, if over this, it should be removed.

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[1] See p. 309.

[2] See p. 317.

[3] See p. 315.

DETERMINATION OF NICKEL BY THE GRAVIMETRIC DIMETHYLGLYOXIME METHOD.

SOLUTIONS REQUIRED.

Dilute Hydrochloric Acid (1 : 10).—Mix 100 cc. of HCl (sp. gr. 1.19) and 1000 cc. of distilled water.

Sodium Hydroxide (2 N).—Dissolve 80 g. of NaOH in 1000 cc. of distilled water.

Dilute Hydrochloric Acid (1 : 1).—Mix 500 cc. of HCl (sp. gr. 1.19) and 500 cc. of distilled water.

Dimethylglyoxime (1-per-cent).—See the Determination of Nickel in Nickel Steel by the Gravimetric Dimethylglyoxime Method.[1]

METHOD.

Treat 2 g. of the sample in a covered beaker with 50 cc. of HCl (sp. gr. 1.19), heat to incipient boiling and then when solution is complete add HNO_3 (sp. gr. 1.42) at intervals and a few drops at a time until the vigorous action which ensues ceases. Digest until the tungstic acid is bright yellow. Add 100 cc. of boiling water, boil for one minute, cool somewhat and filter. Wash the residue thoroughly with dilute HCl (1 : 10) and reserve the filtrate. Dissolve the tungstic acid in a slight excess of sodium hydroxide solution (2 *N*), boil and filter off any residue. Wash the residue with hot water, discard the filtrate and dissolve the residue in a few cubic centimeters of hot dilute HCl (1 : 1), add the solution to the main reserved filtrate and proceed with the determination of nickel as in the Determination of Nickel in Nickel Steel by the Gravimetric Dimethylglyoxime Method.[1]

Allowable Error.—Percentages of nickel determined by the above method should be accurate to $\pm$ [0.02 + (0.01 $\times$ the percentage of nickel found)].

NOTES.

It is difficult to precipitate nickel and to obtain it free from cobalt when cobalt is preponderant. Complete precipitation may be obtained by adding sufficient dimethylglyoxime to react with both cobalt and nickel and digesting for a longer period, or, by oxidizing the cobalt to the trivalent condition by means of $NaClO_3$ or $(NH_4)_2S_2O_8$ in ammoniacal solution before precipitating with dimethylglyoxime. In either case, the first precipitate should be filtered off, dissolved, and reprecipitated.

Direct weighing of nickel dimethylglyoxime is desirable when small amounts of nickel are concerned. Large precipitates are more conveniently ignited at red heat to NiO. In this case, care must be taken to prevent sublimation of the undecomposed salt. This may be accomplished by enclosing the wet paper and precipitate in one or two wet ashless papers and slowly igniting so that the papers char before taking fire. In this way the compound is decomposed and ignition may proceed at full red heat.

[1] See p. 301.

DETERMINATION OF NICKEL BY THE CYANIDE TITRATION METHOD. (ROUTINE.)

SOLUTIONS REQUIRED.

Dilute Hydrochloric Acid (1 : 10).—Mix 100 cc. of HCl (sp. gr. 1.19) and 1000 cc. of distilled water.

METHOD.

Treat 2 g. of the sample in a covered beaker with 50 cc. of HCl (sp. gr. 1.19), heat to incipient boiling and then when solution is complete add HNO_3 (sp. gr. 1.42) at intervals and a few drops at a time until the vigorous action which ensues ceases. Digest until the tungstic acid is bright yellow. Add 100 cc. of boiling water, boil for one minute, cool somewhat and filter. Wash the residue thoroughly with dilute HCl (1 : 10) and determine nickel in the filtrate as in the Determination of Nickel in Nickel Steel by the Cyanide Titration Method.[1]

NOTE.

In case cobalt is present, the preliminary separation (*a*) as given in the cyanide titration method must be employed.

DETERMINATION OF COBALT.

SOLUTIONS REQUIRED.

Sodium Carbonate (10-per-cent).—Dissolve 100 g. of Na_2CO_3 in 1000 cc. of distilled water.

Ammonium Acetate (5-per-cent).—Dissolve 50 g. of $NH_4C_2H_3O_2$ in 1000 cc. of distilled water.

Dilute HCl (1 : 1).—Mix 500 cc. of HCl (sp. gr. 1.19) and 500 cc. of distilled water.

Acidulated Hydrogen Sulfide Water.—Mix 20 cc. of H_2SO_4 (sp. gr. 1.84) and 1000 cc. of distilled water, cool, and saturate with H_2S.

Nitroso Beta Naphthol (7-per-cent).—Prepare as needed by dissolving in the proportion of 7 g. of the compound to 100 cc. of glacial acetic acid.

METHOD.

See the Determination of Silicon by the Acid Attack and Baking at 120° C. Method.[2]

[1] See p. 303.
[2] See p. 323.

Employ the HCl solution reserved in this determination or prepare a similar solution by treatment of a new 1-g. sample in the same fashion, with the difference, however, that the wet tungstic acid is not ignited but treated directly with NaOH solution (2 *N*) for the recovery of its cobalt content.

Evaporate the HCl solution to a volume of approximately 100 cc. and neutralize the acid solution by adding solid Na_2CO_3 until the acid is nearly destroyed and then continuing with care by adding sodium carbonate solution (10-per-cent), drop by drop with vigorous stirring, until the solution has become amber colored and the precipitate dissolves with difficulty. Pour the feebly acid solution slowly and with constant stirring into 200 cc. of boiling ammonium acetate solution (5-per-cent). Boil for two to three minutes, allow to settle, filter without washing on a large rapid filter and reserve the filtrate which must be absolutely clear. Dissolve the precipitate in as little hot dilute HCl (1 : 1) as possible, catching the solution in the unwashed beaker and reprecipitate as before, taking the same precautions as to preliminary neutralization and the volumes employed. Again filter without washing, discard the precipitate and combine the filtrate with that already reserved. The combined filtrates should now be free from iron, chromium and vanadium but may contain such elements as molybdenum, copper and small amounts of tungsten in addition to cobalt, nickel and manganese. To eliminate molybdenum and tungsten and to concentrate the others, neutralize the combined solutions with NH_4OH (sp. gr. 0.90) add 30 cc. in excess, and saturate the solution with a rapid current of H_2S. Allow the precipitate to settle, filter without washing, discard the clear filtrate, and transfer the paper and precipitate to a 250-cc. Erlenmeyer flask. Dissolve any precipitate adhering to the precipitation beaker in 20 cc. of HNO_3 (sp. gr. 1.42) and a little HCl (sp. gr. 1.19), pour the solution on the paper and precipitate and shake until the paper has disintegrated. Add 5 cc. of H_2SO_4 (sp. gr. 1.84) and heat over a free flame until fumes of H_2SO_4 are evolved. In case the organic matter has not been destroyed add a little more HNO_3 and repeat the HNO_3 treatment and the evaporation until fumes of H_2SO_4 appear. Cool, dilute to 100 cc., add 2 cc. of NH_4OH (sp. gr. 0.90) and saturate the acid solution with a rapid current of H_2S. Filter, wash with acidulated H_2S water and discard the precipitate. Boil the filtrate until H_2S has been expelled, and the solution reduced to a volume of 100 cc. and then proceed as in (*a*) or (*b*) below.

(*a*) *Determination of Cobalt by the Electrolytic Method.*

Add 5 cc. of H_2SO_4 (sp. gr. 1.84), neutralize with NH_4OH (sp. gr. 0.90), add 35 cc. in excess and then 2 g. of $NaHSO_3$. Electrolyze in a volume of 150 cc. for 6 hours or overnight, using gauze electrodes and a current density of 0.2 to 0.3 ampere per dm^2. Wash the cathode with cold water, dry at 100° C., and weigh the deposit. The electrolyte usually contains from 0.1 to 1 mg. of nickel and cobalt (mainly cobalt) and should be tested as follows: Boil the electrolyte with an excess of ammonium persulfate, keeping the solution strongly ammoniacal, to precipitate manganese. Filter, wash, and discard the precipitate and saturate the clear ammoniacal filtrate with H_2S. Digest at the side of the steam-bath for 1 hour, filter if a precipitate has appeared, and wash with water containing a little NH_4Cl and $(NH_4)_2S$. Ignite, weigh the combined oxides of nickel and cobalt, multiply by the empirical factor 0.75 and add to the cathode weight. The weight of cobalt must then be found by deducting nickel as determined on a separate portion of the steel or by analysis of the deposit and the small recovery from the electrolyte. In either case, attention must be paid to the difficulty in precipitating small amounts of nickel as pure nickel dimethylglyoxime in the presence of large amounts of cobalt, as described under the Determination of Nickel in Nickel Steel by the Gravimetric Dimethylglyoxime Method.[1]

NOTE.

Tungsten, molybdenum and vanadium must be completely removed in order to obtain a satisfactory deposition of nickel and cobalt.

(*b*) *Determination of Cobalt by the Nitroso-Beta-Naphthol Method.*

Transfer the solution to a 600-cc. beaker, add NH_4OH (sp. gr. 0.90) until the solution is slightly ammoniacal and then HCl (sp. gr. 1.19) until in 5 cc. excess. Dilute to 350 cc., heat to boiling, and for each centigram of cobalt expected add, with constant stirring, 6 cc. of nitroso-beta-naphthol solution (7-per-cent). Set aside until the precipitate has settled, filter on paper, and wash the precipitate twice, alternately with dilute HCl (1 : 1) and water, and finally with hot water. Transfer to a porcelain crucible, heat gently until the carbonaceous matter has been destroyed, and then at a high temperature for 20 minutes. Cool in a desiccator and weigh as Co_3O_4.

Allowable Error.—Percentages of cobalt determined by the above method should be accurate to $\pm$ [0.04 + (0.01 $\times$ the percentage of cobalt found)].

[1] See p. 301.

NOTES.

The ignited oxide does not have the exact formula Co_3O_4 and therefore in case the weight is appreciable it is safer to change the oxide to metallic cobalt by repeated ignition in hydrogen in a Rose-form crucible until the weight is constant.

The precipitate is apt to be contaminated by nickel in case nickel is preponderant in the original solution.

DETERMINATION OF COBALT BY CYANIDE TITRATION. (ROUTINE.)

SOLUTIONS REQUIRED.

Sulfuric-Citric Acid.—Dissolve 200 g. of citric acid in a cooled mixture of 100 cc. of H_2SO_4 (sp. gr. 1.84) and 900 cc. of distilled water.

Dilute Nitric Acid (1 : 3).—Mix 200 cc. of HNO_3 (sp. gr. 1.42) and 600 cc. of distilled water.

Potassium Iodide (10-per-cent).—See the Determination of Nickel in Nickel Steel by the Cyanide Titration Method (Routine).[1]

Standard Silver Nitrate.—See the Determination of Nickel in Nickel Steel by the Cyanide Titration Method (Routine).[1]

Standard Potassium Cyanide.—See the Determination of Nickel in Nickel Steel by the Cyanide Titration Method (Routine).[1]

METHOD.

See the Determination of Silicon by the Acid Attack and Baking at 120° C. Method.[2]

To the reserved HCl solution or one prepared in the same way from a new portion of steel, add 50 cc. of the sulfuric-citric acid solution and then NH_4OH (sp. gr. 0.90) until in 10 to 15 cc. excess. Bring the solution to boiling, add 1 g. of $NaClO_3$, and boil for 5 minutes. Cool, dilute to 200 cc., add dilute HNO_3 (1 : 3), carefully, until the solution is just neutral and then add 5 cc. of NH_4OH (sp. gr. 0.90). Again cool if necessary, add 2 cc. of potassium iodide solution (10-per-cent) and titrate as in the Determination of Nickel in Nickel Steel by the Cyanide Titration Method.[1] The volume of standard cyanide solution which is actually consumed represents the sum of nickel and cobalt. The volume of standard cyanide solution consumed by the nickel may be found and deducted by a determination of nickel as in the Determination of Nickel in Tungsten Steel by the Cyanide

[1] See p. 303.
[2] See p. 323.

Titration Method (Routine) with preliminary separation (*a*)[1] or by calculation based on a determination of nickel as in the Determination of Nickel in Tungsten Steel by the Gravimetric Dimethylglyoxime Method.[2] In either case, the volume of standard cyanide solution consumed by cobalt represents that required to convert cobalt to the compound $K_2Co(CN)_5$ and the cobalt titre of the cyanide solution is best found by titration of material of known cobalt content under the conditions that obtain in the method.

DETERMINATION OF COPPER.

In steels containing little tungsten, proceed as in the Determination of Copper in Plain Carbon Steel.[3]

In steels containing considerable tungsten, proceed as in the Determination of Copper in Plain Carbon Steel[3] with the single exception that the first sulfide precipitate and paper is digested with HNO_3 and H_2SO_4 to complete destruction of organic matter instead of igniting the paper and residue. The H_2SO_4 solution is then cooled, diluted, boiled with an excess of NaOH solution (2 *N*) and treated as in the ordinary procedure.

MOLYBDENUM STEEL.

DETERMINATION OF CARBON.

See the Determination of Carbon in Plain Carbon Steel by the Direct-Combustion Method.[3]

DETERMINATION OF MANGANESE.

(*a*) *Determination of Manganese* (Absence of Chromium and Cobalt).

See the Determination of Manganese in Plain Carbon Steel by the Bismuthate Method.[3]

(*b*) *Determination of Manganese* (Presence of Chromium and Absence of Cobalt).

See the Determination of Manganese in Chrome-Nickel Steel by the Hydrolysis-Bismuthate Method.[4]

(*c*) *Determination of Manganese* (Routine and in Presence of Cobalt).

See the Determination of Manganese in Plain Carbon Steel by the Persulfate Method.[3]

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[1] See p. 330.

[2] See p. 329.

[3] Standard Methods of Chemical Analysis of Plain Carbon Steel (Serial Designation: A 33) of the American Society for Testing Materials, see p. 276.

[4] See p. 306.

DETERMINATION OF PHOSPHORUS.

(*a*) *Determination of Phosphorus* (Absence of Vanadium).

See the Determination of Phosphorus in Plain Carbon Steel by the Molybdate-Magnesia Method.[1]

(*b*) *Determination of Phosphorus* (Presence of Vanadium).

See the Determination of Phosphorus in Chrome-Vanadium Steel by the Modified Molybdate-Magnesia Method.[2]

(*c*) *Determination of Phosphorus* (Routine and in Presence of Vanadium).

See the Determination of Phosphorus in Chrome-Vanadium Steel by the Modified Alkalimetric Method (Routine).[3]

(*d*) *Determination of Phosphorus* (Routine in Absence of Vanadium).

See the Determination of Phosphorus in Plain Carbon Steel by the Alkalimetric Method.[1]

DETERMINATION OF SULFUR.

See the Determination of Sulfur in Plain Carbon Steel by the Oxidation Method.[1]

See the Determination of Sulfur in Plain Carbon Steel by the Evolution-Titration Method (Routine).[1]

NOTES.

The ordinary evolution method yields low values with molybdenum steel Good results are obtained on annealed samples with HCl (sp. gr. 1.19).

DETERMINATION OF SILICON.

See the Determination of Silicon in Plain Carbon Steel by the Nitro-Sulfuric Method.[1]

See the Determination of Silicon in Plain Carbon Steel by the Sulfuric Acid Method (Optional).[1]

DETERMINATION OF MOLYBDENUM
BY
PRECIPITATION AS SULFIDE AND WEIGHING AS LEAD MOLYBDATE.

SOLUTIONS REQUIRED.

Dilute Sulfuric Acid (*1 : 1*).—Pour 500 cc. of H_2SO_4 (sp. gr. 1.84) slowly and with stirring into 500 cc. of distilled water.

[1] Standard Methods of Chemical Analysis of Plain Carbon Steel (Serial Designation: A 33) of the American Society for Testing Materials, see p. 276.

[2] See p. 311.

[3] See p. 313.

Dilute Hydrochloric Acid (1 : 1).—Pour 500 cc. of HCl (sp. gr. 1.19) into 500 cc. of distilled water.

Dilute Hydrochloric Acid (1 : 9).—Pour 100 cc. of HCl (sp. gr. 1.19) into 900 cc. of distilled water.

Bromine Water.—A saturated solution.

Ammonium Persulfate (10-per-cent).—Prepare as needed by dissolving 1 g. of the persulfate in 10 cc. of distilled water.

Acidulated Hydrogen Sulfide Water.—Pour 10 cc. of sulfuric acid (sp. gr. 1.84) into 1000 cc. of distilled water. Add 10 g. of tartaric acid and saturate the solution with H_2S.

Sodium Hydroxide (2 N).—Dissolve 80 g. of NaOH in 1000 cc. of distilled water.

Ammonium Acetate (50-per-cent).—Dissolve 100 g. of ammonium acetate in 100 cc. of distilled water.

Lead Acetate (1-per-cent).—Dissolve 10 g. of lead acetate in a mixture of 990 cc. of distilled water and 10 cc. of acetic acid. Filter if necessary.

Ammonium Nitrate (2.5-per-cent).—Dissolve 25 g. of NH_4NO_3 in 1000 cc. of distilled water, filter if necessary, and make sure that the solution is neutral.

METHOD.

(*a*) *Determination of Molybdenum* (Absence of Tungsten).

In an 800-cc. beaker, dissolve a sufficient amount of the sample to yield approximately 0.03 g. of molybdenum in a mixture of 100 cc. of water and 50 cc. of H_2SO_4 (1 : 1). When effervescence ceases, add 10 cc. of ammonium persulfate solution (10-per-cent), boil to oxidize molybdenum and part of the iron and cool somewhat. (Note 1.) Add 5 g. of tartaric acid (Note 2) nearly neutralize with NH_4OH (sp. gr. 0.90) heat nearly to boiling and pass in H_2S *rapidly* for ten minutes or until the iron has been reduced and the molybdenum precipitated. Allow the solution to stand on the steam-bath at 50 to 60° C. for three hours, filter and wash the sulfur and sulfides with acidulated hydrogen sulfide water. Treat the sulfides as below. Boil the filtrate to expel hydrogen sulfide, and until the volume is reduced to from 400 to 500 cc. Add 10 cc. of ammonium persulfate solution (10-per-cent), boil, and again precipitate with H_2S as above in order to recover any molybdenum which escaped the first precipitation. Wash the main precipitate and the recovered precipitate from the papers into a 400-cc. beaker and dissolve the part remaining on the papers in 20 cc. of hot dilute HCl (1 : 1) and bromine water, the solution being received in the 400-cc. beaker. Finally wash the papers with a little water and ignite

them with the paper reserved below. Dilute the solution to 100 cc., add 20 cc. of HCl (sp. gr. 1.19) and 3 g. of sodium chlorate and boil until the molybdenum sulfide is dissolved. Filter, wash the paper and residue with water, and reserve the filtrate. Ignite the papers and residues at a very low temperature in a deep-form crucible (to avoid volatilization loss of any MoO_3), treat any residue with warm NaOH solution (2 *N*) and pour the solution into the main filtrate. Nearly neutralize the combined solutions with sodium hydroxide solution (2 *N*) and pour the clear *yellow* solution slowly and with stirring into 100 cc. of boiling sodium hydroxide solution (2 *N*) contained in a 400-cc. beaker. After the precipitate has settled, filter and wash thoroughly with hot water. Reserve the filtrate and dissolve the precipitate in hot dilute HCl (1 : 1) and re-precipitate with sodium hydroxide solution (2 *N*) as above (Note 3). Neutralize the combined filtrates with HCl (sp. gr. 1.19) add 5 cc. in excess and evaporate the solution to 250 cc. To the clear solution add 50 cc. of ammonium acetate solution (50-per-cent), heat to boiling and slowly add lead acetate solution (1-per-cent) from a burette dropwise and with continual stirring, until in slight excess. This is usually shown by a clearing of the solution. At this point discontinue the addition of the acetate, boil the solution for two or three minutes while stirring, allow the precipitate to settle somewhat, and test the supernatant liquid with a few drops more of the acetate. When precipitation is complete, boil for ten minutes, allow to settle and filter the supernatant liquid through an ashless filter. Wash 3 or 4 times by decantation with 75-cc. portions of hot ammonium nitrate solution (2.5-per-cent), and finally transfer and complete the washing of the precipitate on the paper. If the precipitate is large or much sulfate was present in the solution, it is advisable to dissolve the first precipitate in hot dilute HCl (1 : 1) and re-precipitate it as above in order to avoid undue contamination by lead sulfate or sodium salts. The precipitate may be carefully ignited directly in a porcelain crucible under oxidizing conditions until the carbon is destroyed or else the paper and precipitate may be dried at 100° C., the precipitate removed from the paper, and the paper carefully ignited separately before the ignition of the main precipitate. In either case the final ignition to $PbMoO_4$ should be at a very dull red heat (Note 4).

(*b*) *Determination of Molybdenum* (Presence of Tungsten).

Treat the sample, in a 400-cc. beaker, with 50 cc. of dilute HCl (1 : 1), and when solution is complete add 10 cc. of HNO_3 (sp. gr. 1.42) to oxidize the iron and the tungsten. Digest until the tungstic acid

is bright yellow, filter and wash with dilute HCl (1 : 9). Reserve the precipitate. Add 30 cc. of dilute H_2SO_4 (1 : 1) to the filtrate, evaporate until fumes of H_2SO_4 appear, cool and add 40 cc. of water. If a light residue of tungstic acid separates, filter it off on a small filter, wash with a little dilute sulfuric acid, and treat it together with the main tungstic acid precipitate. Add 3 g. of tartaric acid to the clear solution, nearly neutralize with NH_4OH (sp. gr. 0.90), precipitate the molybdenum as sulfide in slightly acid solution and proceed as above. In order to recover the molybdenum which is always carried down by tungstic acid, dissolve the tungstic acid residues by pouring hot sodium hydroxide solution (2 *N*) upon them and finally wash the papers with a little hot dilute sulfuric acid. To the filtrate add 5 g. of tartaric acid, make slightly acid with sulfuric acid, and precipitate as above with hydrogen sulfide. Any molybdenum recovered here is apt to be contaminated by tungsten and therefore the precipitate must be dissolved in a little HCl and bromine water as above, treated with 2 cc. of H_2SO_4 (sp. gr. 1.84) evaporated until fumes of H_2SO_4 appear, cooled and diluted with 6 cc. of water. After warm digestion, filter off the dissolved molybdenum, wash with water containing a little H_2SO_4, add the solution to the reserved major portion, and proceed as in method (*a*).

Allowable Error.—Percentages of molybdenum determined by the above method should be accurate to $\pm$ [0.02 + (0.02 $\times$ the percentage of molybdenum found)].

NOTES.

1. Molybdenum is very slowly and incompletely precipitated by H_2S when in a reduced state.

2. Tartaric acid is necessary to prevent the partial precipitation of vanadium and tungsten by H_2S. These are the main interfering elements in any method for the determination of molybdenum.

3 The two sodium hydroxide precipitations are necessary to completely separate molybdenum from iron which would otherwise be precipitated upon boiling in dilute acetic acid solution.

4. $PbMoO_4$ is somewhat soluble in ammonium acetate solution, but this reagent is necessary to prevent contamination by $PbSO_4$. If the solution contained no sulfates, a more desirable method would consist in precipitating the molybdate in a hot, very dilute HNO_3 solution by means of $Pb(NO_3)_2$, and then, when the precipitate became granular, making the solution faintly alkaline with ammonia and faintly acid with acetic acid.

5. Molybdenum may also be satisfactorily determined by carefully igniting the sulfide to the oxide MoO_3, weighing, and then correcting for iron and copper oxides or, by dissolving the sulfide in acid, freeing the solution from copper, arsenic, and iron, reducing in a Jones' reductor containing ferric alum and phosphoric acid in the receiver, and titrating the reduced oxide (Mo_2O_3) to MoO_3 by means of a standard permanganate solution.

DETERMINATION OF MOLYBDENUM BY SODIUM HYDROXIDE SEPARATION, LEAD MOLYBDATE PRECIPITATION.

(ROUTINE.)

SOLUTIONS REQUIRED.

Sodium Hydroxide (*2 N*).—See the Determination of Molybdenum by Precipitation as Sulfide and Weighing as Lead Molybdate.[1]

Ammonium Acetate (*50-per-cent*).—See the Determination of Molybdenum by Precipitation as Sulfide and Weighing as Lead Molybdate.[1]

Lead Acetate (*1-per-cent*).—See the Determination of Molybdenum by Precipitation as Sulfide and Weighing as Lead Molybdate.[1]

Dilute Hydrochloric Acid (*1 : 4*).—Pour 200 cc. of HCl (sp. gr. 1.19) into 800 cc. of distilled water.

Dilute Hydrochloric Acid (*5 : 100*).—Pour 50 cc. of HCl (sp. gr. 1.19) into 1000 cc. of distilled water.

METHOD.

(*a*) *Determination of Molybdenum by Sodium Hydroxide Separation, Lead Molybdate Precipitation* (Absence of Tungsten and Vanadium).

Dissolve 2 g. of the sample in 20 cc. of HCl (sp. gr. 1.19), oxidize with 5 cc. of HNO_3 (sp. gr. 1.42) and expel oxides of nitrogen. Add sodium hydroxide solution (2 *N*) until the excess of free acid is neutralized, taking care not to produce a red solution (dissolved hydrate) or a precipitate (basic molybdate). Heat the solution to boiling, and run the solution of the steel in rapid drops from a tap funnel into 160 cc. of sodium hydroxide solution (2 *N*) with constant stirring of the mixture. Dilute the alkaline solution to exactly 500 cc., filter through a dry filter, discard the first few cubic centimeters, and then take exactly 250 cc. of the filtrate. Neutralize the solution with HCl (sp. gr. 1.19) add 5 cc. in excess, boil, add 20 cc. of ammonium acetate solution (50-per-cent), and proceed as in the Determination of Molybdenum by Precipitation as Sulfide and Weighing as Lead Molybdate,[1] omitting, however, a second precipitation of the lead molybdate.

NOTES.

The above process is of fairly general application. Manganese, nickel, cobalt, aluminum, and the ordinary elements of steel are without influence in the method.

[1] See p. 335.

Chromium may be partially oxidized to chromate in the alkali treatment but can be reduced to the harmless trivalent condition by adding a few drops of sulfurous acid to the acid solution, prior to the molybdate precipitation. Tungsten and vanadium interfere. Vanadium is not easily removed but the interference of tungsten can be largely overcome by the modification of the method indicated in method (*b*).

(*b*) *Determination of Molybdenum by Sodium Hydroxide Separation, Lead Molybdate Precipitation* (Presence of Tungsten and Absence of Vanadium).

Dissolve 2 g. of the sample in a covered beaker in 50 cc. of HCl (sp. gr. 1.19), heat to incipient boiling and digest on a hot-plate at moderate heat. Add a few drops of HNO_3 (sp. gr. 1.42), wait until the vigorous action ceases, and continue the dropwise addition of the acid until the vigorous action ceases. If this is carefully done, no tungstic acid separates at this stage. Next evaporate the liquid as quickly as possible until tungstic acid begins to separate, and then more slowly until the solution is pasty. Now add 50 cc. of dilute HCl (1 : 4), boil, and set aside for at least 15 minutes. Filter through paper pulp, wash with dilute HCl (5 : 100) and treat the hydrochloric acid solution for molybdenum as above.

DETERMINATION OF MOLYBDENUM BY THE COLORIMETRIC METHOD.

(OPTIONAL ROUTINE.)

(ABSENCE OF TUNGSTEN AND HIGH VANADIUM OR COPPER.)

SOLUTIONS REQUIRED.

Dilute Sulfuric Acid (*1 : 7*).—Carefully mix 100 cc. of H_2SO_4 (sp. gr. 1.84) and 700 cc. of distilled water.

Dilute Nitric-Sulfuric Acid Mixture.—Mix 833 cc. of HNO_3 (sp. gr. 1.20) and 167 cc. of H_2SO_4 (1 : 1).

Sulfuric-Hydrochloric Acid Mixture.—Mix 450 cc. of H_2SO_4 (1 : 1), 100 cc. of HCl (1 : 1), and 450 cc. of distilled water.

Ferric Sulfate.—Dissolve 70 g. of ferric sulfate in a mixture of 120 cc. of HCl (1 : 1), 500 cc. of H_2SO_4 (1 : 1), and 380 cc. of distilled water. Filter if necessary.

Chromic Sulfate.—Dissolve 50 g. of chromic potassium sulfate in 100 cc. of H_2SO_4 (1 : 1), and 200 cc. of water and heat until the purple color changes to green. Dilute to 1000 cc.

Stannous Chloride.—Dissolve 250 g. of stannous chloride in 200 cc. of HCl (sp. gr. 1.19), and dilute to 1000 cc. with distilled water.

Standard Molybdenum Solution.—Weigh accurately such an amount of a standard ferro-molybdenum (preferably over 50 per cent molybdenum) as will represent exactly 0.5 g. of molybdenum, and transfer the sample to a platinum dish. Add 20 cc. of dilute HNO_3 (1 : 1), and a few cubic centimeters of hydrofluoric acid, warm until the alloy is dissolved and then add 20 cc. of H_2SO_4 (1 : 1) and evaporate until fumes of H_2SO_4 appear. Cool, add 50 cc. of water, boil until all salts are dissolved and then cool and transfer to a liter flask. Add 100 cc. of H_2SO_4 (1 : 1) and dilute the solution to the mark.

Potassium Thiocyanate (5-per-cent).—Dissolve 50 g. of KCNS in 1000 cc. of distilled water.

METHOD.

Transfer 0.5 g. of the steel to a 200 cc. casserole, dissolve in 10 cc. of the nitric-sulfuric mixture, and then evaporate until fumes of H_2SO_4 are evolved. Cool, add 30 cc. of sulfuric-hydrochloric mixture and heat until the salts are in solution. Cool the solution, transfer to a comparison bath and place in a bath for further cooling. To another comparison tube add 25 cc. of the ferric sulfate solution (0.5 g. Fe), 1 cc. of the chromic sulfate solution for each per cent of chromium present, and then 1 cc. of the standard molybdenum solution for each 0.1 per cent of molybdenum expected. Cool both tubes to the same temperature and add to each from a burette 5 cc. of potassium thiocyanate solution (5-per-cent). Mix the solution in each tube, add 10 cc. of the stannous chloride solution to each from a burette and well mix each solution for 10 seconds. With dilute H_2SO_4 (1 : 7), dilute the standard to some multiple of its molybdenum content and dilute the test until the colors match. The amounts of molybdenum are then directly proportional to the heights of the columns of liquids.

NOTES.

The above method is applicable to steels containing up to 0.5 per cent of molybdenum. Above this percentage the solution of the steel must be divided into aliquot portions and the iron and the hydrochloric acid in the standard varied accordingly.

If the analyst is dealing with steels of approximately the same composition, the iron, chromium (nickel) and molybdenum may be combined so that a single 25-cc. portion is used as the standard.

The amount of hydrochloric acid must be regulated and be the same in the tests as excessive hydrochloric acid causes a fading of the color.

If the steel contains chromium in excess of 1 per cent, difficulty may be encountered in obtaining complete solution after the evaporation to the appearance of fumes of H_2SO_4. In this event, dissolve 0.5 g. of the steel, contained in a 200-cc. flask, in 15 cc. of dilute H_2SO_4 (1 : 1), and 30 cc. of distilled water. When solution

is complete, add 15 cc. of $(NH_4)_2S_2O_8$ solution (15-per-cent) and boil, add 3 cc. of dilute HCl (1 : 1), boil 10 minutes to expel the excess of persulfate, and to reduce the volume to 30 cc. preliminary to comparison. If any residue remains, add paper pulp, filter, reserve the filtrate, and transfer the paper and pulp to a 150-cc. beaker and add 10 cc. of HNO_3 (sp. gr. 1.42), 5 g. of sodium chlorate and 5 cc. of H_2SO_4 (sp. gr. 1.84). Evaporate to the appearance of copious fumes and repeat the treatment if the solution is not free from color due to organic matter. Cool and add to the reserved filtrate.

DETERMINATION OF COPPER.

See the Determination of Copper in Plain Carbon Steel.[1]

DETERMINATION OF NICKEL.

See the Determination of Nickel in Nickel Steel by the Gravimetric Dimethylglyoxime Method.[2]

See the Determination of Nickel in Nickel Steel by the Cyanide Titration Method (Routine).[3]

DETERMINATION OF CHROMIUM.

See the Determination of Chromium in Chrome-Nickel Steel by the Persulfate Oxidation Method.[4]

DETERMINATION OF VANADIUM.

See the Determination of Vanadium in Chrome-Vanadium Steel by the Electrolytic Separation Method.[5]

See the Determination of Vanadium in Chrome-Vanadium Steel by Reduction with Ferrous Sulfate and Titration with Permanganate Method (Routine).[6]

DETERMINATION OF TUNGSTEN.

See the Determination of Tungsten in Tungsten Steel by the Acid Digestion-Cinchonine Method.[7]

See the Determination of Tungsten in Tungsten Steel by the Digestion with Acids Method (Routine).[8]

DETERMINATION OF COBALT.

See the Determination of Cobalt in Tungsten Steel by the Sulfide Method.[9]

See the Determination of Cobalt in Tungsten Steel by the Cyanide Titration Method (Routine).[10]

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[1] Standard Methods of Chemical Analysis of Plain Carbon Steel (Serial Designation: A 33) of the American Society for Testing Materials, see p. 276.

[2] See p. 301. [3] See p. 303. [4] See p. 309. [5] See p. 315. [6] See p. 317.
[7] See p. 324. [8] See p. 326. [9] See p. 330. [10] See p. 333.

STANDARD METHODS OF DETERMINING WEIGHT OF COATING ON ZINC-COATED ARTICLES[1]

Serial Designation: A 90 – 24

These methods are issued under the fixed designation A 90; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1923; ADOPTED, 1924.

SHOP WEIGHING TESTS

Select a pickled and washed sheet. Stand the sheet on edge and allow to drain for 2 minutes. The water remaining on the sheet will then amount to approximately 0.01 lb. per sq. ft.

Weigh this sheet with an accuracy of 0.05 lb., and subtract the weight of the water to obtain the real weight of the uncoated sheet. After galvanizing, reweigh the sheet. The increase in weight represents the coating.

Where greater accuracy is desired, wash, dry and weigh ten sheets; then coat and reweigh.

To determine the weight of coating in ounces per square foot, divide the weight of coating in ounces by the area in square feet in the sheet or sheets.

SAMPLING

(*a*) *Sheets.*

The laboratory samples for determining the average weight of coating upon a galvanized sheet shall be taken as follows:

A $2\frac{1}{2}$-in. strip shall be cut transversely or diagonally across the middle of the sheet with its ends approximately 1 in. from each edge. Three samples, $2\frac{1}{4}$ by $2\frac{1}{4}$ in., shall be accurately cut from the middle and the two ends of this strip. These samples shall be cleaned with gasoline or benzol, then with alcohol and dried thoroughly before proceeding with the test.

The weight of coating in grams on a $2\frac{1}{4}$ by $2\frac{1}{4}$-in. piece (5.08 sq. in.) is numerically equal to the coating in ounces per square foot.

(*b*) *Wire.*

Select either exactly 1 ft. of wire, or a definite length of wire as given in Table I, depending upon the diameter of the wire after

[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee A-5 on Corrosion of Iron and Steel.

stripping. Clean the wire with gasoline or benzol, then with alcohol, and dry thoroughly.

When using exactly 12-in. of wire for the test and obtaining the loss of weight (weight of coating) in grams, the formula is as follows:

$$\frac{\text{Loss of Weight in grams}}{7.422 \times \text{diameter in inches of stripped wire}} = \text{Ounces per square foot of actual surface}$$

It is sometimes more convenient to use a length of wire, as given in Table I, such that the loss in weight (weight of coating) in grams will numerically equal the ounces per square foot of actual surface.

TABLE I.—LENGTHS OF WIRE TO GIVE GRAMS OF COATING WHICH ARE NUMERICALLY EQUAL TO OUNCES PER SQUARE FOOT OF ACTUAL SURFACE

SIZE OF WIRE, B. W. G.	DIAMETER, IN.	LENGTH FOR TEST IN.	LENGTH FOR TEST CM.
0	0.340	4¾	12.1
1	0.300	5⅜	13.7
2	0.284	5 11/16	14.5
3	0.259	6¼	15.9
4	0.238	6 13/16	17.3
5	0.220	7⅜	18.7
6	0.203	7 15/16	20.2
7	0.180	9	22.8
8	0.165	9 13/16	24.9
9	0.148	10 15/16	27.7
10	0.134	12 1/16	30.6
11	0.120	13½	34.2
12	0.109	14 13/16	37.7
13	0.095	17	43.2
14	0.083	19½	49.5
15	0.072	22 7/16	57.0
16	0.065	24¾	63.2
17	0.058	27⅞	70.8
18	0.049	33	83.8

By multiplying by two, the figures for coating in ounces per square foot of actual surface may be compared with the figures for coating in ounces per square foot on zinc-coated sheets.

HYDROCHLORIC ACID - ANTIMONY CHLORIDE METHOD
(STANDARD METHOD)

SOLUTIONS REQUIRED

Antimony Chloride Solution.—Dissolve 20 g. of antimony trioxide or 32 g. of $SbCl_3$ in 1000 cc. of HCl (sp. gr. 1.19).

Hydrochloric Acid.—Concentrated HCl (sp. gr. 1.19).

METHOD

(*a*) *Sheets.*

Cut three $2\frac{1}{4}$ by $2\frac{1}{4}$-in. laboratory samples, as described under Sampling, and weigh together[1] after cleaning and drying. They should be immersed singly in 100 cc. of hydrochloric acid (sp. gr. 1.19) to which has been added 5 cc. of antimony chloride solution, and allowed to remain therein until the evolution of hydrogen has ceased or until only a few bubbles are being evolved. This requires only about 15 to 30 seconds, except in the case of sherardized coatings which require a somewhat longer time. The same 100 cc. of hydrochloric acid can be used for at least 5 samples, but 5 cc. of the antimony chloride solution should be added before the immersion of each sample. After stripping, the samples should be washed and scrubbed under running water, dried with a towel and laid in a warm place for a short time. The samples should again be weighed together[1] and the number of grams lost divided by the number of samples taken. Each gram then corresponds numerically to one ounce of coating per square foot.

(*b*) *Wire.*

A small section of the zinc-coated wire should be stripped in hydrochloric acid containing antimony chloride, and the diameter of the stripped wire determined.

To determine the weight of coating, the sample is carefully weighed to 0.01 g. The wire is then placed in a tall cylinder containing hydrochloric acid (sp. gr. 1.19) to which has been added 2 to 3 cc. of antimony chloride solution of the same strength as is used in the testing of sheets. After stripping, the wire is washed under running water, dried, and laid in a warm place for a short time. The loss in weight represents the zinc coating, and if the length of wire designated in Table I is used, the coating in grams will be numerically equal to the coating in ounces per square foot of actual surface. In order to compare this figure with that given for sheets, it must be multiplied by two.

BASIC LEAD ACETATE METHOD

(ALTERNATE METHOD)

SOLUTIONS REQUIRED

Lead Acetate Solution.—Dissolve 400 g. of crystallized lead acetate in 1 liter of water. When dissolved, add 4 g. of finely powdered litharge and after thorough agitation, allow the solution to settle and decant the clear portion for use.

[1] If it is of interest to know the individual weight of coating on each piece, each must be analyzed individually instead of collectively as described.

METHOD

Cut three $2\frac{1}{4}$ by $2\frac{1}{4}$-in. laboratory samples, clean and weigh as described in the Hydrochloric Acid - Antimony Chloride Method.[1] The samples should then be submerged separately in a tumbler containing sufficient lead acetate solution to cover the samples. The samples should be maintained in an upright position in order to enable the lead acetate to attack all portions.

After being immersed about three minutes, the sample should be taken out and the adherent lead carefully removed under running water in order that no burnishing action will cause the lead to plate onto the sample. Four immersions of three minutes each are usually sufficient to remove all zinc from the sample, when the bright surface of the iron will be exposed. The test pieces should then be washed in water, dried carefully and weighed. The loss in grams divided by the number of samples represents the weight of coating in grams, which is numerically equal to the weight of coating in ounces per square foot.

SULFURIC ACID PERMANGANATE METHOD
(ALTERNATE METHOD)

SOLUTIONS REQUIRED

Distilled water should be used in all cases where water is mentioned as a reagent.

Standard Potassium Permanganate, 0.1 N.—Dissolve pure, crystallized potassium permanganate in water in the proportion of 3.2 g. per liter. Allow to stand at least two weeks and filter through asbestos. Standardize the solution in the following manner:

Weigh accurately 0.45 to 0.5 g. of U. S. Bureau of Standards' sodium oxalate. Place in a 400-cc. beaker and dissolve in 250 cc. of water at 80 to 90° C. Add 10 cc. of sulfuric acid composed of 5 cc. of water and 5 cc. of c.p. H_2SO_4 (sp. gr. 1.84) and titrate the solution at once with the potassium permanganate solution, stirring the liquid vigorously and continuously. The permanganate must not be added more rapidly than 10 to 15 cc. per minute and the last 0.5 to 1 cc. must be added dropwise with particular care to allow each drop to be completely decolorized before the next is introduced. The solution should not be below 60° C. by the time the end point is reached. More rapid cooling may be prevented by allowing the beaker to stand on a small asbestos-covered electric hot plate during the titration. The use of a small thermometer as a stirring rod is

[1] If it is of interest to know the individual weight of coating on each piece, each must be analyzed individually instead of collectively as described.

most convenient. Calculate the iron equivalent of the permanganate solution using the iron value furnished by the Bureau of Standards for the sodium oxalate used.

Sulfuric Acid.—Mix 100 cc. c.p. H_2SO_4 (sp. gr. 1.84), with 900 cc. of water.

METHOD

Carefully weigh the $2\frac{1}{4}$ by $2\frac{1}{4}$-in. piece, containing exactly 5.08 sq. in.

After determining the weight of the plate, place the piece in a 250-cc. beaker (Griffin form). Allow the piece to rest on or come in contact with a small piece of platinum foil. Add 125 cc. or a sufficient amount of the sulfuric acid solution to cover the inclined piece. Cover the beaker with a watch glass and allow the zinc coating to dissolve. In from ten to twenty minutes the zinc will be dissolved, as will be indicated by the cessation of the rapid evolution of gas, disregarding the small amount of gas coming mainly from the edges of the plate, due to the action of the acid on the base plate. Wash the plate with a jet of water from a wash bottle, allowing the washings to run into the beaker. Wipe the plate dry, and immediately titrate the solution in the beaker with the standard potassium permanganate solution and calculate the weight of iron dissolved with the zinc coating. Weigh the plate, and subtract this weight from the weight of the plate before removal of the coating. From the difference deduct the weight of iron found to have been dissolved with the coating, which will give the weight in grams of zinc coating on 5.08 sq. in. of the sample. The weight of the zinc coating in grams on the $2\frac{1}{4}$ by $2\frac{1}{4}$-in. piece will be numerically equal to the weight of zinc coating in ounces per square foot.

APPENDIX

FIELD TESTS FOR DETERMINATION OF ZINC-COATED ARTICLES

PREECE OR COPPER SULFATE DIP TEST

The samples for the Preece test may be of any size, but should be free from as much cut surface as possible, and should be carefully cleaned before starting the test. The samples are then dipped into not less than 100 cc. of copper sulfate solution maintained at a temperature of 18° C. The samples are allowed to remain exactly one minute in the solution. They are then washed in running water, and the copper deposit lightly rubbed off. Successive immersions of one minute each are continued, with the washing and cleaning of the sample between each one, until the appearance of bright adherent copper indicates that the iron beneath the coating has been exposed. Should a small

amount of copper be coated adherently to the zinc coating, it must not be mistaken for the end point in which the copper plates out onto the iron. The appearance of copper within one inch of a cut surface is likewise not considered to be the end point of the test.

The copper sulfate solution is prepared by dissolving 36 parts of commercial copper sulfate crystals in 100 parts of water, then adding enough cupric oxide to neutralize any free acid. The solution is filtered or allowed to settle and decanted, then diluted with water until its specific gravity is 1.186 at 18° C. It should always be used at this temperature.

When material is tested by the Preece or copper sulfate method, the number of one-minute immersions which the sample shall withstand is specified.

The amount of coating removed by a one-minute immersion in the copper sulfate solution is roughly between 0.20 and 0.25 oz. per sq. ft. of actual surface, or double this per square foot of sheets.

This test is not as accurate in determining the average weight of coating upon a sample as is the hydrochloric acid - antimony chloride method, but is useful, however, in determining which are the thinnest portions of the coating.

THERMAL METHOD[1]

This method makes possible the determination of the zinc coating on iron and steel sheets and other articles without necessitating the use of an analytical balance. An accurately measured galvanized sample is immersed in a measured amount of acid, the maximum temperature rise being recorded. Each 0.1° rise in temperature is equivalent to a definite weight of zinc.

The apparatus necessary for conducting this test is as follows:

1. Testing jar, about 2½ in. in inside diameter, with a capacity of about 400 cc., flaring at the top if possible.
2. Thermometer, graduated in 0.1° C., with a range of about 50° C.
3. 300-cc. graduated cylinder.
4. Glass-stoppered bottle containing concentrated hydrochloric acid (sp. gr. 1.19).
5. Rule for measuring.

The sample is cleaned with gasoline, dried and accurately measured. For testing zinc-coated sheet, the usual 2¼ by 2¼-in. specimen may be used, and for wire, suitable lengths may be used as given in the table under Sampling of Wire.

A measured amount of hydrochloric acid (usually 200 cc.) is poured into the testing jar. The temperature of the acid is recorded after stirring, and the sample is immersed in the acid, care being taken that the acid does not overflow the jar. During this time, and until the coating has been stripped from the piece, the temperature is watched until the highest point is reached and the temperature starts to decline. The rise in temperature is then recorded, and from a table of factors prepared for various quantities of acid, the amount of zinc may be calculated. From the number of grams of zinc and the area of the piece in square inches, the weight of coating may be calculated as follows:

$$\text{Coating, ounces per square foot, actual surface} = \text{Weight of zinc in grams} \times \frac{5.08 \text{ sq. in.}}{\text{Area, sq. in.}}$$

[1] Described in paper by D. M. Strickland, "A Method for Determining the Spelter Coating on Iron and Steel Sheets by Measuring the Rise in Temperature of the Acid Employed," *Proceedings*, Am. Soc. Testing Mats., Vol. 22, Part II, p. 227 (1922).

In this formula, the total area, that is, both sides of the sheet, is measured. To place this on the ordinary sheet basis, as expressed on zinc-coated sheet, the above figure should be doubled. For very light coatings (about 1 oz. per sq. ft.) 100 cc. of acid are sufficient. With coatings of 2½ oz. per sq. ft. or heavier, 300 cc. of acid should be used. To standardize the equipment, 5 or 6 zinc-coated specimens of any convenient gage or size are weighed, the rise in temperature determined for the apparatus, thermometer and volume of acid. The samples are washed, dried and reweighed, and the difference in weight noted. The weight loss in grams is divided by the corresponding rise in temperature in degrees. When carefully determined, the average of the above 5 or 6 determinations will give a conversion factor which is reliable for the equipment used and for the volume of acid employed. Factors may be determined for any volume of acid in like manner.

EVOLUTION OF HYDROGEN METHOD

This method consists in measuring the hydrogen evolved from the action of hydrochloric acid containing antimony chloride upon a definite area of galvanized surface. By this method, it is not required to cut any portion of the article to be tested, as with the Cushman coating tester, a 2½-in. ring is sealed to a portion of the surface. Acid is then added which attacks the coating within the area of the ring, and the evolved hydrogen is measured by a suitable gas burette. After removal of the spent acid, the stripped spot is washed, dried and may either be painted or coated with a suitable metallic coating. The article is, therefore, not mutilated. A full description of the test is found in the 1920 Proceedings of the American Society for Testing Materials.[1]

The results obtained by this method check very closely with those obtained by the regular hydrochloric acid - antimony chloride method. The main objection to this method is the fact that the coating upon only one side of a sheet is obtained, and as the coating upon galvanized sheets is not always exactly the same on each side; doubling the figures obtained on one side of the sheet will not always give the real amount of coating on both sides of the sheet.

This tester finds use, however, when it is necessary to test sheets or culverts already installed, and where it is desired that the articles shall not be mutilated as would be necessary in taking a regular sample.

[1] Allerton S. Cushman, "A New Method of Testing Galvanized Coatings," *Proceedings*, Am. Soc. Testing Mats., Vol. XX, Part II, p. 411 (1920).

STANDARD METHODS OF DETERMINING WEIGHT OF COATING ON TIN, TERNE, AND LEAD-COATED SHEETS[1]

Serial Designation: A 91 – 24

These methods are issued under the fixed designation A 91; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1923; ADOPTED, 1924.

SAMPLING

From each grade or shipment take one sheet for analysis. Cut four 2 by 2 in. pieces; one from each of the four sides of the sheet, parallel with and about ½ in. from the sides, and near the middle of each side,—or cut similar samples from corner, middle, and opposite corner of the sheet, keeping in at least one inch from the edge in each case.

NOTE.—For more accurate work, nine samples are cut, three from across the top, three across the middle, and three across the bottom of each sheet.

DETERMINATION OF WEIGHT OF COATING

METHOD

Clean the laboratory samples with chloroform, carbon tetrachloride, benzol or gasoline and finally with alcohol, and dry thoroughly; then weigh accurately the four pieces together.

Wrap a stiff platinum or nickel wire about the 2 by 2 in. piece in such a manner that it may be held in the acid in a horizontal position. Using a 400-cc. beaker, heat from 60 to 150 cc. of sulfuric acid (sp. gr. 1.84) to 250° C. Immerse the sample for about one minute in the hot acid, then remove and momentarily immerse in 50 cc. of distilled water contained in a 600-cc. beaker. Rub the surface with a "policeman," while washing with about 50 cc. of distilled water from a wash bottle. If the coating has not been completely removed, again immerse in the acid and repeat the procedure. Treat all four samples in the same manner, using the same acid. Thoroughly dry and reweigh the samples. If desired, the samples may be retained for the analysis of the base metal.

[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee A-5 on Corrosion of Iron and Steel.

The loss in weight represents the coating together with some iron.

Cool the sulfuric acid in which the samples were stripped and combine with the washings in a 600-cc. beaker. Pour the solution into a 1000-cc. volumetric flask, and rinse the beaker with hydrochloric acid (sp. gr. 1.12). Add rinsings to the flask and fill to the mark with hydrochloric acid of the same strength, again adjusting to the mark if necessary after cooling.

If it is desired to make a direct determination of the lead, the lead chloride should all be in solution. For heavy lead-coated sheets it may, therefore, be necessary to dilute the solution to 2000 cc. with hydrochloric acid (sp. gr. 1.12), in order to have all the lead chloride in solution.

The solution may now be analyzed for iron, tin, lead or any other elements.

DETERMINATION OF IRON

METHOD

Remove an aliquot portion of 200 cc. from the 1000-cc. volumetric flask to a 600-cc. beaker. Add 1 or 2 cc. of a saturated solution of potassium permanganate to oxidize the iron and tin, and heat the solution to boiling. Cool and add a slight excess of ammonia. Filter the solution and wash the precipitate with hot water. Dissolve the precipitate in the original beaker with hydrochloric acid (sp. gr. 1.12), and hot water. Evaporate the hydrochloric acid solution to a volume of about 10 cc. and reduce with stannous chloride.

To the cooled solution add a mixture of 25 cc. of a saturated mercuric chloride solution, 10 cc. of phosphoric acid manganese sulfate solution and 400 cc. of boiled distilled water. Titrate immediately with 0.1 *N* potassium permanganate solution. Calculate the amount of iron stripped from the four pieces, from the number of cubic centimeters of permanganate used.

CALCULATION OF THE WEIGHT OF COATING

From the loss in weight of the four 2 by 2-in. pieces, subtract the amount of iron found by the above test. This figure represents the weight of coating in grams on the four pieces.

CALCULATION FACTORS

The weight of coating in grams on the four 2 by 2-in. pieces multiplied by 4.3210 = weight of coating in pounds per box of 112 sheets, 14 by 20 in.

multiplied by 8.6421 = weight of coating in pounds per case of 112 sheets, 20 by 28 in.

multiplied by 0.3175 = weight of coating in ounces per square foot.

Pounds of coating per case of 112 sheets, 20 by 28 in., multiplied by 0.03673 = ounces per square foot.

Ounces per square foot multiplied by 27.22 = pounds per case of 112 sheets, 20 by 28 in.

DETERMINATION OF TIN ON TERNE PLATE

METHOD

Remove an aliquot portion of 200 cc. from the volumetric flask. Place in a 300-cc. Erlenmeyer flask, and add 1 g. of powdered antimony. Fit the flask with a one-hole rubber stopper containing a glass tube bent twice at right angles, with the end of the short bend projecting through the stopper, the other end being long enough to reach almost to the bottom of a beaker placed on a level with the flask. This beaker contains about 300 cc. of dilute sodium bicarbonate solution made up with boiled distilled water.

Place the flask on the hot plate, with the glass tube extending into the beaker of sodium bicarbonate solution. After boiling for about five minutes, substitute the beaker of dilute sodium bicarbonate solution with another containing about 50 cc. of a saturated solution of sodium bicarbonate dissolved in boiled distilled water, and remove both the beaker and flask to a cool place. This will cause a small amount of sodium bicarbonate to enter the flask and exclude the air. Finally bring the solution to a low temperature. Add several cubic centimeters of starch solution and titrate with 0.05 *N* iodine solution. It is desirable to run a duplicate analysis for tin adding the iodine quickly to a point slightly less than the end point found in the previous determination, then finishing the titration.

From these determinations, calculate the percentage of tin in the coating. In the case of tin plate, the amount of tin can be calculated to pounds per box or pounds per case by factors given under Calculation of Weight of Coating.

DETERMINATION OF LEAD ON TERNE PLATE

METHOD

After ascertaining that all the lead chloride is in solution, remove an aliquot portion of 100 cc. from the volumetric flask and place in a

400-cc. beaker. Add 10 cc. of sulfuric acid (sp. gr. 1.84), cover, and evaporate to fumes of sulfuric anhydride. Cool and dilute to 300 cc. with water. Allow to settle and then filter on a weighed Gooch crucible, washing with 5-per-cent sulfuric acid solution. Dry and ignite at a dull red heat. Cool and reweigh. The gain in weight multiplied by 0.6831 equals the weight of lead, from which calculate the percentage of lead in the sample.

DETERMINATION OF TIN ON TIN-COATED SHEETS

METHOD

Bend or cut up each sample and place each in a separate Erlenmeyer flask and cover with about 40 cc. of strong hydrochloric acid. Connect each flask through a rubber stopper with a source of pure oxygen-free carbon dioxide. Dissolve on a hot plate with carbon dioxide passing through to exclude air. Cool the flask in running water and titrate immediately with standard iodine solution, using starch indicator. The iodine solution is made up so that 1 cc. is equivalent to 0.005786 g. of tin, and is standardized against pure tin. The number of cubic centimeters of iodine used divided by ten reads directly in pounds of tin per base box of plate.

NOTE.—A base box contains 112 sheets, 14 by 20 in., and weighs 100 lb.

When it is desired to analyze only a small number of samples, satisfactory results may be obtained by adding to the flask, with the sample, a small pinch of pure powdered antimony. Cover with a watch glass and dissolve at boiling temperature. As soon as solution is complete, insert a rubber stopper with glass tube extending just through the stopper, and bent twice at right angles, the long end extending approximately level with the bottom of the flask. Insert the long end of the tube into a dilute solution of sodium bicarbonate. Place the flask in cold running water, and as the flask cools, the bicarbonate solution is sucked into the flask, the carbon dioxide set free driving out the air. As soon as cool, titrate as above.

STANDARD METHODS OF TEST

FOR

MAGNETIC PROPERTIES OF IRON AND STEEL[1]

Serial Designation: A 34 – 27

These methods are issued under the fixed designation A 34; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ADOPTED, 1911; REVISED, 1912, 1914, 1918, 1924, 1926, 1927.

A. Normal Induction and Hysteresis

DEFINITIONS

Definitions.

1. (*a*) *Normal Induction.*—The induction, produced under a given magnetizing force, in a substance which has been previously demagnetized and then subjected to a sufficient number of reversals of the given magnetizing force to bring it to a cyclic condition.

Both the induction and magnetizing force shall be expressed in terms of the c.g.s. electromagnetic units (gauss and gilbert per centimeter respectively).

(*b*) *Magnetic Permeability.*—The ratio of the normal induction to the magnetizing force which produces it. Thus:

$$\text{Permeability} = \frac{\text{Gausses}}{\text{Gilberts per centimeter}}$$

(*c*) *Residual Induction.*—The magnetic induction which exists in a substance after the magnetizing force has been reduced to zero.

NOTE.—If the induction has been reduced from a point on the normal induction curve it is called the normal residual induction.

(*d*) *Coercive Force.*—The negative value of magnetizing force required to reduce the induction in a substance to zero.

NOTE.—If the induction has been reduced to zero from a point on the normal induction curve the coercive force is called the normal coercive force.

[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee A-6 on Magnetic Properties.

TEST SPECIMENS

Test Specimens.

2. (*a*) Test specimens may consist of rings, straight bars or strips of uniform cross-section.

(*b*) Ring specimens shall be continuous, having no joints or welds. The ratio of mean diameter to radial width shall be not less than 10.

(*c*) Sharp shears or dies shall be used in the preparation of specimens of sheet material. If the radial width of ring specimens or the width of straight strips of sheet material is less than 3 cm. ($1\frac{3}{16}$ in.), the punching or cutting strains shall be removed before testing by an annealing process acceptable to both manufacturer and purchaser.

(*d*) Test specimens of sheet material consisting of straight strips shall be cut half parallel and half at right angles to the direction of rolling, and in types of test requiring companion samples each half shall contain an equal number of each kind of strips.

Size of Specimen.

3. (*a*) Test specimens of sheet material shall have a cross-sectional area of not less than 2 sq. cm. (0.31 sq. in.) nor more than 4 sq. cm. (0.62 sq. in.) and shall be so selected from not less than two sheets that their properties shall represent as nearly as practicable the average properties of the sheets. (See Figs. 1 and 2.)

(*b*) The cross-section of specimens of sheet material shall be calculated from measured values of length and mass and measured or assumed values of density.

(*c*) For silicon steels, a density of 7.7 g. per cu. cm. shall be assumed if the silicon content is 2 per cent or less and a density of 7.5 g. per cu. cm. shall be assumed if the silicon content is over 2 per cent.[1]

(*d*) For nickel-iron alloys the density shall be assumed from the nickel content as given by the straight lines joining the points defined as follows:[2]

NICKEL, PER CENT	DENSITY, G. PER CU. CM.
0	7.85
30	8.00
100	8.90

(*e*) For other alloys, a density corresponding to the actual measured or estimated value shall be used.

4. Specimens of magnet steel shall be hardened previous to testing in accordance with a procedure acceptable to both manufacturer and purchaser.

[1] For silicon steel having a 2-per-cent silicon content the electrical resistance is 2.6 ohms per meter gram.

[2] For 50-per-cent nickel content the density is 8.26 g. per cu. cm. For 80-per-cent nickel content the density is 8.64 g. per cu. cm.

STANDARD DATA

Standard Data.

5. (*a*) The standard normal-induction data for all magnetic materials shall consist of corresponding values of normal induction and magnetizing force at suitable intervals within the range of values agreed upon by the manufacturer and purchaser.

(*b*) Residual-induction and coercive-force values for transformer core material and material of the type used for electromagnet cores shall be determined from a maximum normal induction of 10,000 gausses.

(*c*) For permanent magnet steel, the residual induction and coercive force shall be determined from the maximum normal induction corresponding to a magnetizing force of 200 gilberts per cm. unless

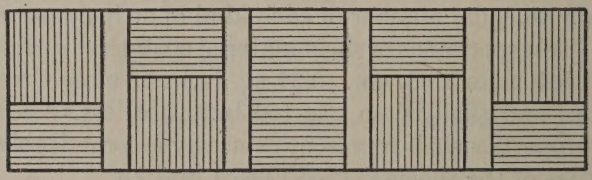

FIG. 1.

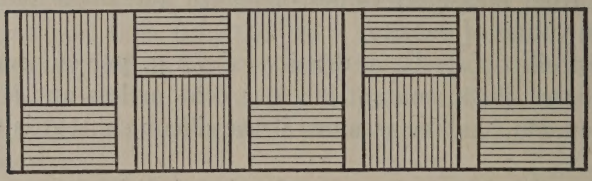

FIG. 2.

the maximum permeability is less than 100, in which case the maximum magnetizing force shall be not less than $2\frac{1}{2}$ times the value of the magnetizing force at which this maximum permeability occurs and shall be some multiple of 200.

METHODS OF TEST

Apparatus.

6. The tests may be made by means of one of the following methods:

The Rowland Ring Method.—This method may be used for any material and any magnetizing forces.

The Burrows Compensated Double Yoke.—This type of apparatus is suitable for tests at magnetizing forces up to 300 gilberts per cm. For higher magnetizing forces, serious difficulty due to heating may be encountered unless special temperature control is provided.

The magnetizing coils shall be not less than 20 cm. ($7\frac{7}{8}$ in.) in length and the ratio of the area of the test coil to that of the specimen shall be such that the air correction factor shall be not greater than 5. This air correction may be applied by calculation or eliminated by means of an adjustable mutual inductance, having its primary in series with the main permeameter magnetizing winding and its secondary in series with the main test coil. This mutual inductance shall be set to such a value that the flux in the space between the sample and the test coil shall be automatically compensated for. If desired, the two main magnetizing coils may be connected in series and the average values for the whole sample[1] determined by connecting the two middle test coils in series and using them as one. In this arrangement, four auxiliary test coils near the ends of the specimens are connected in series and used as one coil for adjusting the current in the compensating magnetizing coils.

The Fahy Simplex Permeameter.—This type of apparatus is suitable for tests at magnetizing forces up to 300 gilberts per cm. without difficulties due to heating. For higher values of magnetizing force, the high magnetization adapter may be used.

Isthmus Method.—This method, as described in U. S. Bureau of Standards *Scientific Papers Nos. 361* and *383*, is suitable for tests at magnetizing forces exceeding 200 gilberts per cm.

ACCURACY

7. (*a*) The accuracy of the results of magnetic tests depends not only upon the method or apparatus used but also upon the nature of the specimen. The most common sources of error are (1) lack of uniformity in permeability along the length of the specimen, (2) mechanical strain, and (3) temperature variations. Errors due to these causes are indeterminate and may be large. Accuracy.

(*b*) For specimens having a satisfactory degree of uniformity, clamped so as to be free from mechanical strain and kept at a constant temperature within 5° C., the methods specified above may be expected to give the following accuracy: For normal induction, the values of magnetizing force corresponding to inductions up to an induction equal to two-thirds of that corresponding to the maximum magnetizing force specified in Section 5 (*c*) should be accurate within 3 per cent, provided the permeability does not exceed 10,000. This permeability limitation does not apply to the ring method. Values of induction greater than the above should be accurate within 1 per

[1] The limits of cross-sectional area given in Section 3 (*a*) shall apply to each half of the whole sample.

cent. For residual induction, values should be accurate within 2 per cent and for coercive force within 5 per cent.

B. Core Loss

DEFINITIONS

Definitions.

8. (*a*) *Core Loss.*—The power consumption in electrical sheet steel when subjected to an alternating magnetization.

(*b*) *Standard Core Loss.*—The total power in watts consumed in each kilogram of material at a temperature of 25° C. when subjected to a harmonically varying induction having a maximum of 10,000 gausses and a frequency of 60 cycles per second, when determined in accordance with definite prescribed methods. It is represented by the symbol $W^{10}/_{60}$.

NOTE.—If the loss corresponding to a higher induction is desired, the sample should be subjected to a harmonically varying induction having a maximum of 14,000 gausses. The corresponding symbol will be $W^{14}/_{60}$.

(*c*) *Aging Coefficient.*—The percentage change in the standard core loss after continued heating at 100° C. for 600 hours.

PROCEDURE

Conditions of Testing.

9. The standard core loss shall be measured under the following conditions:

(*a*) The magnetic circuit shall consist of 10 kg. (22 lb.) of the test material, cut with a sharp shear into strips 50 cm. ($19\frac{11}{16}$ in.) in length and 3 cm. ($1\frac{3}{16}$ in.) in width, one-half parallel and one-half at right-angles to the direction of rolling, made up into four equal bundles, two containing material parallel and two containing material at right angles to the direction of rolling, and finally built into the four sides of a square with butt joints and opposite sides consisting of material cut in the same manner. No insulation other than the natural scale of the material (except in the case of scale-free material) shall be used between laminations, but the corner joints may be separated by tough paper 0.1 mm. (0.004 in.) in thickness.

(*b*) The magnetizing winding shall consist of four solenoids surrounding the four sides of the magnetic circuit and joined in series. A secondary coil shall be used for energizing the voltmeter and the potential coil of the wattmeter.

These solenoids shall be wound on a form of any non-magnetic non-conducting material of the following dimensions:

Inside cross-section	4 by 4 cm.
Thickness of wall	not over 0.3 cm.
Winding length	42 cm.

The primary winding on each solenoid shall consist of 150 turns of copper wire uniformly wound over the 42-cm. length. The total resistance of the magnetizing winding shall be between 0.3 and 0.5 ohm. The secondary winding of 150 turns of copper wire on each solenoid shall be similarly wound beneath the primary winding. Its resistance shall not exceed 1 ohm.

(*c*) A voltmeter and the voltage coil of a wattmeter shall be connected in parallel to the terminals of the secondary winding of the apparatus. The current coil of the wattmeter shall be connected in series with the primary winding.

(*d*) An electromotive force having a wave form approximating a sine curve shall be applied to the primary winding and adjusted until the voltage of the secondary circuit is given by the equation:

$$E = \frac{4 f N n B M}{4 l D 10^8}$$

in which

f = form factor of primary E.M.F. . . . = 1.11 for sine wave
N = number of secondary turns. . . . . = 600
n = number of cycles per second. . . . . = 60
B = maximum induction, gausses. . . . = 10 000
M = total mass in grams. . . . . = 10 000
l = length of strips in centimeters. . . . = 50
D = density, g. per cu. cm. . . . . = { 7.5 for high-resistance steel / 7.7 for low-resistance steel
E = { 106.6 volts for high-resistance steel for sine voltage / 103.8 volts for low-resistance steel for sine voltage

NOTE.—For the 14,000-gauss test the voltages will be as follows:

E = { 149.2 volts for high-resistance steel for sine voltage. / 145.2 volts for low-resistance steel for sine voltage.

The form factor of the applied electromotive force shall not depart more than 1 per cent from the value of 1.11. As an alternative to the use of a sine wave, the correct value of the voltage may be determined by applying it to an Epstein apparatus containing a sample which has been standardized by means of a sine wave electromotive force. The wattmeter is brought to the correct reading for the standard sample. The corresponding voltage is the correct one to use.

Density.

10. (*a*) For silicon steels, a density of 7.7 g. per cu. cm. shall be assumed if the silicon content is 2 per cent or less and a density of 7.5 g. per cu. cm. shall be assumed if the silicon content is over 2 per cent.[1]

[1] For silicon steel having a 2-per-cent silicon content the electrical resistance is 2.6 ohms per meter gram.

(*b*) For nickel-iron alloys the density shall be assumed from the nickel content as given by the straight lines joining the points defined as follows:[1]

NICKEL, PER CENT	DENSITY, G. PER CU. CM.
0	7.85
30	8.00
100	8.90

(*c*) For other alloys a density corresponding to the actual measured or estimated value shall be used.

Core Loss. 11. The wattmeter gives the power consumed in the iron and the secondary circuit. The loss in the secondary circuit is given in terms of the total resistance and voltage. Subtracting this correction term from the total power gives the net power consumed in the steel as hysteresis and eddy-current loss. Dividing this value by ten gives the core loss in watts per kilogram.

Sampling. 12. The core-loss material shall be cut from two or more sheets taken at random from shipment. The strips should be distributed symmetrically over the sheet, as nearly as may be practicable. (See Figs. 1 and 2.)

It is recommended that a test sample shall represent not more than 5000 kg. (11,000 lb.).

Procedure. 13. (*a*) Cut the test material into strips 3 by 50 cm. as indicated in Section 13.

(*b*) Place on the balance a pile of strips weighing 2.5 kg. Add a second pile of the same kind, bringing the weight up to 5 kg. In each case the weight shall be taken to the nearest strip. Add in succession two piles of 2.5 kg. each, of the other kind of strips, bringing the weight up to 7.5 kg. and 10 kg., respectively.

(*c*) Insert in the apparatus as indicated.

NOTE.—If desired, for convenience, the bundles may be loosely secured by tape or string (not wire).

(*d*) Apply the alternating voltage to the primary coil and tap the joints together until the current has a minimum value, as shown by an ammeter in series. Then clamp the corners firmly by some suitable device.

(*e*) Shunt the ammeter and adjust the primary current until the voltmeter indicates the proper value. This adjustment may be made by an auto-transformer, by varying the field of the alternator, or by both, but not by the insertion of resistance or inductance in the

[1] For 50-per-cent nickel content the density is 8.26 g. per cu. cm. For 80-per-cent nickel content the density is 8.64 g. per cu. cm.

primary circuit. Simultaneously the frequency must be adjusted to 60 cycles.

(*f*) Read the wattmeter.

(*g*) *Calculations.*—Subtract from the wattmeter reading the instrument losses, which will be constant for any set of instruments and voltage, and divide by 10. The result is the standard core loss.

NOTE.—If desired a 5-kg. sample may be used for routine acceptance tests, provided it is cut from at least two sheets, except in case of a dispute between the manufacturer and purchaser when the 10-kg. sample shall be used.

RECOMMENDED PRACTICE
FOR
ANNEALING OF MISCELLANEOUS ROLLED AND FORGED CARBON-STEEL OBJECTS[1]

Serial Designation: A 35-24

This recommended practice is issued under the fixed designation A 35; the final number indicates the year of original adoption or, in the case of revision, the year of last revision.

ADOPTED, 1911; REVISED, 1921, 1924.

1. *Purpose and General Procedure.*—The usual purpose in annealing miscellaneous forged or rolled carbon-steel objects is to remove existing coarseness of grain. This removal is brought about by heating the object to an annealing temperature, which varies with the carbon content of the metal. But the rate at which the object cools from this annealing temperature influences its properties very profoundly. Hence this rate of cooling should be suited to the duties which the object has to perform in service, and hence to the properties which we seek to give it.

Therefore these specifications first consider the annealing temperature to which the piece must be heated in order to remove existing coarse grain, and then the rate of cooling from that temperature.

Under certain special conditions an annealing is required in order to remove, not coarseness of grain, but the effects of rolling or otherwise working the metal at a temperature so low as to set up serious internal stress. Appropriate treatment for these conditions is given in Section 14.

As these specifications are intended to apply to a great variety of miscellaneous objects, they are purposely made suggestive rather than mandatory in many respects, because no single set of rules can be applied rigorously to such widely varying classes of objects and purposes.

ANNEALING FOR REMOVING EXISTING COARSE GRAIN.

2. *Method of Heating.*—In the case of large objects, the heating of the interior of which lags behind that of the outside,

[1] Under the standardization procedure of the Society, this recommended practice is under the jurisdiction of the A.S.T.M. Committee A-4 on Heat Treatment of Iron and Steel.

the final approach to the annealing temperature aimed at should be slow, so that the interior may be brought fully up to it without carrying the exterior far beyond it, because in general any needlessly high temperature is injurious, and tends to re-coarsen the grain. The temperature should be held long enough at the annealing point to insure that the whole of the interior reaches that point, and that the refining of the grain may become complete. An exposure of 45 minutes should be long enough for each inch of thickness.

3. *Control of Temperature. Pyrometers.*—For all important work in careful hands the use of some trustworthy pyrometer is strongly recommended. But most pyrometers should be checked frequently against some standard. For those who are unwilling to take this trouble it is safer to rely on a trained eye than on an unchecked pyrometer. The operator should have clearly before him the fact that no pyrometer indicates the temperature of the interior of the object heated, and that the temperature which most pyrometers indicate is one between the temperature of the outside of the object heated and the temperature of the flame which is supplying the heat. Wherever practicable the part of the pyrometer which is supposed to reach the temperature of the object heated should be in immediate contact with that object, and should be protected from the flame or other source of heat by a suitable insulation, as for instance by covering it with sand. In important cases the gas or other source of heat should be shut off for at least ten minutes before taking the observation.

4. *Control Without the Use of a Pyrometer.*—In working without a pyrometer and relying on the eye, the light surrounding the furnace should be dull, and should be kept as nearly constant as practicable, in order that the eye may not be misled by the changing contrasts between the surrounding light and that of the object heated. In particular, direct sunlight should be excluded, and any arc or other strong lights should be so placed that neither they themselves nor any concentrated part of their light is in the field of the operator's sight when he is estimating by eye the temperature of the objects to be annealed. Allowance should be made for the brighter surroundings by day than at night, and on sunny than on dark days.

5. *Magnetic Indications.*—The annealing temperature for steels containing between 0.50 and 0.90 per cent of carbon is that at which the metal suddenly ceases to be magnetic. This

fact may sometimes be used for the purpose of fixing or verifying the annealing temperature.

6. *Annealing Temperature.*—In general, the higher the carbon content the lower should be the annealing temperature. Hence different temperatures are given for different ranges of carbon content. Further, in order to bring the interior of large objects up to an effective annealing temperature, their outside may often be raised advantageously somewhat above that temperature. Hence for each range of carbon content a range of temperature is given. The upper limit of this range applied (1) to larger objects, and (2) to the lower part of the range of carbon content given.

The following ranges of temperature should be used for the several ranges of carbon content indicated. They refer to the usual moderate manganese content. For steels with a manganese content greater than 0.75 per cent slightly lower temperatures suffice.

RANGE OF CARBON CONTENT.	RANGE OF ANNEALING TEMPERATURE.
Less than 0.12 per cent	875 to 925° C. (1607–1697° F.)
0.12 to 0.29 "	840 " 870 " (1544–1598 ")
0.30 " 0.49 "	815 " 840 " (1499–1544 ")
0.50 " 1.00 "	790 " 815 " (1454–1499 ")

7. *Care in Heating.*—Care should be taken that all parts of the object reach the same temperature. To that end it may be necessary to mask from the heat, by means of bricks, the thinner part of objects of varying thickness. When the heating is nearly finished, these bricks may be removed. In particular the flame should never be allowed to touch any part of the object under treatment.

8. *Cooling.*—After the object has been held at the annealing temperature long enough to make its temperature nearly uniform throughout, and to complete the refining of the grain, it should be cooled in a way suited to its carbon content and to giving it the specific properties needed. The general principles are: first, the higher the carbon the slower should be the cooling; and second, the slower the cooling the softer and more ductile the metal will be, and the lower will be its tensile strength, elastic limit, and yield point. The greatest softness and ductility are obtained at a certain sacrifice of strength and elasticity, and the greatest strength and elasticity at a certain sacrifice of softness and ductility.

For most purposes neither of these extremes is desired, and it is not only sufficient as regards quality but economical to remove the object from the furnace as soon as it has been thor-

oughly annealed, and to allow it to cool in air, always completely protected not only from rain and snow but from sharp drafts of air. Objects containing more than 0.50 per cent of carbon should cool more slowly till the color dies out, say at 500° C. (932° F.), as for instance by leaving them in the furnace. They may then be removed and cooled in air. Further, thin objects containing between 0.25 and 0.50 per cent of carbon should be treated like those of 0.50 per cent of carbon, unless they can be so massed together that their collective bulk will retard their cooling, so that they will collectively cool even in air with moderate slowness, like single large objects.

SPECIAL ANNEALING METHODS.

9. The foregoing methods are economical because they release the furnaces early for further use. In case special qualities are desired the following methods may be used:

10. *To Give the Greatest Softness and Ductility* of which the metal is capable, even at a certain sacrifice of strength and elastic limit, for instance for ease of machining or to resist a small number of severe distortions, the metal should be cooled slowly, either within the furnace, or in the case of large objects, under a cover of lime, clay, or other slow conductor of heat. The slower the cooling and the lower the temperature to which slow cooling is carried, the softer and weaker will be the steel. But for most cases for which even unusual softness and ductility are required, it suffices to remove the object from the furnace when it has become dead black, and to cool it thenceforth in air.

11. *To Give Great Tensile Strength and High Elastic Limit* even at a certain sacrifice of ductility, the cooling should be more rapid, the rapidity to be governed by the thickness and carbon content of the object. Thin objects and those with high carbon content cannot stand so rapid a cooling as thick and low-carbon ones, lest their ductility be too far sacrificed. For instance, thick objects with less than 0.50 per cent of carbon may be cooled completely in air, of course protected from rain or snow. Objects with 0.50 per cent of carbon or more, and thin objects with from 0.30 to 0.50 per cent of carbon, may be cooled in air if their cooling is somewhat retarded, as for instance by massing them together, as happens in the case of rails.

12. *To Give an Unusually High Combination of Ductility with Tensile Strength and Elastic Limit. Water or Oil Quenching and Annealing.*—This process needs great care and intelligence,

and should in general be used only by those familiar with high-grade steels. After holding at the annealing temperature suited to the particular steel, as indicated in Section 6, the object is quenched in oil, which should be kept in circulation. It may be quenched in water if its carbon content is so low and its shape so simple that it is not in danger of cracking or receiving permanently harmful stress. In any event the danger of such cracking and stress is lessened by removing the object from the oil or water before it has cooled completely, say when its temperature has fallen to 160° C. (320° F.). It should if possible not cool below 100° C. (212° F.) and certainly not below 20° C. (68° F.). The annealing should begin within a very few hours after the quenching and if possible without ever allowing the piece to cool below 100° C. (212° F.) and certainly not below 20° C. (68° F.).

The steel thus hardened should next be annealed by heating to a temperature suited for giving the properties needed. In general the higher this annealing goes, the more ductile will the steel become, and the lower will be its strength and elastic limit.

For very high elastic limit and tensile strength, anneal at 500 to 650° C. (932 to 1202° F.). In this case the ductility will be low. Some steels, such as watch-springs and shafting, are annealed at 350° C. Little commercial annealing is done below 500° C.

For intermediate tensile strength, elastic limit, and ductility, best suited to the majority of cases, anneal at 600 to 650° C. (1112 to 1202° F.).

For the greatest ductility, with good strength and elastic limit, anneal at from 725 to 750° C. (1337 to 1382° F.).

The object should be held at this second annealing temperature long enough not only to allow its interior to reach it, but also to relieve the stress given in the water or oil quenching. For pieces of moderate thickness a 4-hour exposure should suffice.

13. *To Give a Moderate Increase of Strength and Elastic Limit above that Given by a Simple Slow Cooling, without the Full Sacrifice of Ductility which a Simple Air Cooling would Cause.*— After holding at the annealing temperature suited to the carbon content, as indicated in Section 6, hasten the cooling till the object is at a dull red, say 650° C. (1202° F.), and henceforth cool slowly. The hastening of the cooling may be brought about in the case of thin objects in relatively shallow furnaces by opening the furnace door till the temperature falls to dull redness; or by running the objects out into the air on a movable car-

bottom, and returning them to the furnace when they have cooled to dull redness. In cases in which such operations are to be performed frequently, special unfired chambers may be used for the final slow cooling, thus leaving the annealing furnaces proper available for their regular work. The results obtained in this way are not as good as those obtained with the method described in Section 11.

14. *Special Annealing to Remove the Effects of Rolling or Otherwise Working the Object in the Cold or at any Unduly Low Temperature.*—The object should be heated to about 775° C. (1427° F.) and cooled with a slowness which should increase with the thickness, that is, the least dimension of the piece. In the case of thin plates a mere heating to 725° C. (1337° F.), followed immediately by slow cooling, should suffice. In the case of thick forgings, in which much time may be needed to allow severe stress to relieve itself, the sojourn at 775° C. (1427° F.) may be prolonged for several hours, though always at the cost of superficial decarburizing.

Such annealing for steel containing less than 0.15 per cent carbon should be at 900° C. (1652° F.). Large grain size may be caused by annealing very low carbon steel in the neighborhood of 700° C. (1292° F.), after cold working.

RECOMMENDED PRACTICE
FOR
HEAT TREATMENT OF CARBON-STEEL CASTINGS[1]

Serial Designation: A 36 - 24

This recommended practice is issued under the fixed designation A 36; the final number indicates the year of original adoption or, in the case of revision, the year of last revision.

ADOPTED, 1914; REVISED, 1924.

Scope.

1. This recommended practice is intended solely for guidance, and is not to be construed as entering in any manner into specifications of the American Society for Testing Materials.

Types of Treatment.

2. This recommended practice is intended to cover:

(*a*) Annealing.
(*b*) Normalizing.
(*c*) Normalizing followed by a reheating.
(*d*) Quenching followed by a reheating.

Cooling After Pouring.

3. After pouring, the castings should be allowed to cool in the sand to a temperature below the critical range.

Cleaning.

4. The castings should be sufficiently cleaned of adhering sand before heat treatment to insure thorough and uniform heating.

Temperature When Above Upper Critical Point.

5. The temperatures recommended when treatment above the upper critical point is desired should vary with the carbon content, approximately as follows:

CARBON, PER CENT	TEMPERATURE
Up to 0.40, inclusive	900° C. (1650° F.)
Over 0.40 to 0.60, inclusive	850° C. (1560° F.)
Over 0.60	830° C. (1525° F.)

Control of Temperatures.

6. The use of pyrometers (preferably recording pyrometers) is recommended. Pyrometers should be checked frequently against a standard. Every precaution should be taken to procure due assurance that the castings throughout the furnace reach the required temperature.

Heating.

7. After cooling as indicated in Section 3, the castings should then be heated slowly and uniformly to the desired temperature.

[1] Under the standardization procedure of the Society, this recommended practice is under the jurisdiction of the A.S.T.M. Committee A-4 on Heat Treatment of Iron and Steel.

Sufficient time should be allowed for the heat to accomplish the desired structural transformations throughout the mass of the castings. For these reasons it is necessary that each furnace containing castings be held for a prolonged period at the desired temperature after the castings have attained that temperature. It is recommended that this prolonged period should be not less than 60 minutes for each inch of thickness of the thickest casting segment in the charge.

Annealing.

8. To anneal castings properly they should be heated as described in Section 7 to one of the temperatures given in Section 5. They should then be slowly cooled in the furnace until they reach a faint red color, after which the cooling may be continued in air.

Normalizing.

9. To secure finer structure (with probably less ductility than can be obtained by annealing as described in Section 8) castings should be heated as described in Section 7 to one of the temperatures given in Section 5, and cooled in still air.

Normalizing Followed by a Reheating.

10. To secure fine structure, accompanied by great ductility, normalizing as described in Section 9 should be followed by a reheating and subsequent cooling. In this reheating, the castings may be kept for a short time just above the lower critical point or they may be kept for several hours at a suitable temperature below the critical range. After this reheating the castings should be cooled slowly in the furnace until they reach a faint red color (provided they reach this color in the reheating), after which the cooling may be continued in air.

Quenching Followed by a Reheating.

11. To secure maximum refinement of the structure coupled with the greatest possible combination of strength and toughness, castings should be heated as described in Section 7 to one of the temperatures given in Section 5, and quenched in water or oil. They should then be reheated. In this reheating, the castings may be kept for a short time just above the lower critical point or they may be kept for several hours at a suitable temperature below the critical range. After this reheating the castings should be cooled slowly in the furnace until they reach a faint red color (provided that color was reached in the reheating operation), after which the cooling may be continued in air.

Precautions for Quenching.

12. (*a*) Certain castings which from their mass or design would crack on quenching if kept in the water or oil until completely cold may be safely treated by removing them from the quenching bath when they have reached a black heat, immediately charging them into a furnace heated to approximately the same temperature as the castings, and reheating them as described in Section 11.

(*b*) The advisability of attempting to quench and reheat any given casting must be considered with judgment in the light of experience; and to attempt to apply this method of heat treatment without taking the precautions demanded by the shape, size, and sections of each individual casting can only result in the loss of many castings through the development of cracks either in quenching, in reheating, or at some later time.

RECOMMENDED PRACTICE
FOR
CARBURIZING AND HEAT TREATMENT OF CARBURIZED OBJECTS[1]

Serial Designation: A 37 – 27

This recommended practice is issued under the fixed designation A 37; the final number indicates the year of original adoption or, in the case of revision, the year of last revision.

ADOPTED, 1914; REVISED, 1927.

Scope.

1. This recommended practice is intended solely for guidance, and is not to be construed as entering in any manner into specifications of the American Society for Testing Materials.

Purpose and General Procedure.

2. Carburizing is intended to increase the carbon content in the surface layers of low-carbon steel objects so they may be made hard and wear-resistant on the outside with a strong, tough, inner portion or core. This type of structure is suitable for parts which are required to stand considerable shock and friction. The process consists in heating the steel in contact with a carbonaceous material for a long time at temperatures above the critical temperature of the steel.

Factors Governing the Process.

3. The primary factors governing the process are:

(*a*) Chemical composition of the steel;
(*b*) The carburizing operation;
(*c*) The hardening operation.

Chemical Composition of Steel.

4. The steel should be selected according to the service requirements. A well-made carbon steel will be satisfactory for most ordinary purposes. The carbon content of simple and alloy steels should preferably be below 0.20 per cent. High manganese above 0.60 per cent is sometimes specified to obtain increased hardness and increased core strength. High phosphorus and sulfur contents improve the machineability but generally indicate a steel of poor quality. These elements are, however, often added intentionally to steels of good quality to improve their machining qualities.

[1] Under the standardization procedure of the Society, this recommended practice is under the jurisdiction of the A.S.T.M. Committee A-4 on Heat Treatment of Iron and Steel.

In alloy steels, nickel tends to retard the grain growth at carburizing temperatures, depresses the critical temperature, and allows the steel to be hardened at lower quenching temperatures. Chromium is used alone in percentages up to 1.25 per cent and gives a greater abrasive hardness to the case. S. A. E. Steel No. 3115, containing about 1.25 per cent nickel and 0.60 per cent chromium is recommended for general high grade use. A molybdenum content of about 0.25 per cent or combined with about 1.75 per cent of nickel is used with

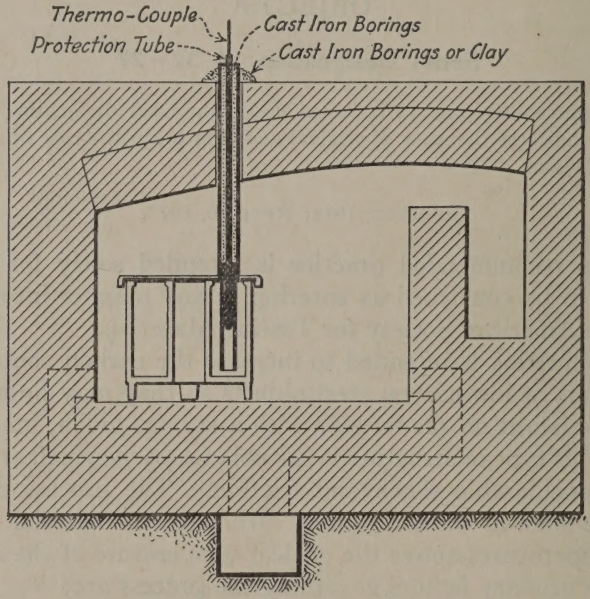

FIG. 1

good results. The use of molybdenum steel containing chromium is not recommended as this steel has an inherent tendency to distort in the carburizing operation.

Compounds. 5. Carburizing materials are divided into three general classes: solids, liquids, and gases, the solid type being generally used. The recommendations given apply to this type only. Commercial compounds are usually better than those made by the user. One part of new solid compound to three parts of used compound is recommended as a shop mixture. The used compounds should be screened to remove the dust.

Containers. 6. Packing pots are made from cast iron, cast and pressed steel and special heat-resisting alloys. The latter are recommended. Comparisons are usually made on a heat-hour-cost basis, the life of

the containers being determined by actual service and this figure divided into the cost of the pot which gives the cost per service-heat-hour. The proportions of the pot in relation to the parts to be carburized is of primary importance as well as the proper distribution of metal in the walls, reinforcement ribs, legs, etc. A compromise in size is found between the very small containers which are expensive in handling practice and the large containers which have a tendency to heat unevenly. The size of the pot should be governed by the size of the parts.

Temperature.

7. The effective temperature is the temperature inside the pot. The carburizing time should be designated as the number of hours at the carburizing temperature. The heating through of the pots is judged in two ways: by estimating with the eye, and by placing thermocouples inside the pot as shown in Fig. 1. The latter method is recommended except on pots which are so small that it would be impracticable to place a thermocouple inside them.

Pyrometers.

8. The use of recording pyrometers is recommended. Where the method shown in Fig. 1 is used, an extra couple should be placed in the furnace so that the furnace temperature may be more readily controlled, as otherwise excessive furnace temperatures or extremely variable heats may be obtained.

Heating.

9. Quick heating to the carburizing temperature will cause more distortion of the parts than slow heating. The temperature in any pot must be comparable with the temperature inside any other. To this end, the furnace must be designed to heat evenly and the pots must be spaced on the furnace hearth so that they will be heated evenly and uniformly.

Carburized Zone.

10. The carbon content at the surface of the work increases with the carburizing temperature. The formation of free carbide at the grain boundaries is undesirable, as it leaves a very brittle surface exposed to the service stresses. The surface carbon should not exceed 1.15 per cent. This will be reduced by the finish grinding operation. The carbon content is governed by the carburizing compound and the temperature while gradation depends upon the analysis of the steel and the rate of cooling. The allowable temperature depends upon the nature of the work. Temperatures of 941 to 954° C. (1725 to 1750° F.) may be used where speed and low expense are primary considerations. For general practice, 899° C. (1650° F.) is recommended. The carburizing temperature should be lowered about 38° C. (100° F.) when the regenerative quench is not to be used. Thin cases, of 0.010 to 0.015 in., are better obtained with a carburizing temperature of 843° C. (1550° F.).

TABLE I.—RECOMMENDED TEMPERATURES AND COOLING MEDIUMS TO BE USED FOR CARBURIZING AND HEAT TREATMENT OF CARBURIZED OBJECTS.

The temperatures and cooling mediums given in this table are dependent upon and must be varied according to the instructions given in the main section of the recommended practice. Particular attention should be given to varying the regenerative quench with the size of the part and the degree of distortion which must be avoided.

S. A. E. Steel No.	Composition						Preliminary Heat Treatments (use either A or B)									Carburizing			Refining and Hardening Treatments								
							Treatment A			Treatment B																	
							Normalizing Temperature		Cool in	Quenching Temperature		Cool in	Reheat to		Cool in	Temperature		Cool in	Regenerative Temperature		Cool in	Hardening Temperature		Cool in	Tempering Temperature	
	Carbon, per cent	Manganese, per cent	Phosphorus, maximum per cent	Sulfur, maximum per cent	Nickel, per cent	Chromium, per cent	deg. Cent.	deg. Fahr.		deg. Cent.	deg. Fahr.		deg. Cent.	deg. Fahr.		deg. Cent.	deg. Fahr.		deg. Cent.	deg. Fahr.		deg. Cent.	deg. Fahr.		deg. Cent.	deg. Fahr.
1020	0.15–0.25	0.30–0.60	0.045	0.05	.....	.....	900	1650	air	900	1650	oil	595	1100	air	900	1650	pots	871	1600	oil	775	1425	brine	205	400
1015	0.10–0.20	0.30–0.60	0.045	0.05	.....	.....	900	1650	air	900	1650	or	595	1100	air	900	1650	pots	871	1600	oil	775	1425	brine	205	400
1025	0.20–0.30	0.50–0.80	0.045	0.05	.....	.....	900	1650	....	.....	.....	water	595	1100	air	900	1650	pots	871	1600	oil	775	1425	brine	205	400
2320	0.15–0.25	0.50–0.80	0.04	0.045	3.25–3.75	.....	925	1700	air	830	1525	oil	595	1000	air	900	1650	pots	829	1525	oil	745	1375	oil	165	325
2315	0.10–0.20	0.30–0.60	0.04	0.045	3.25–3.75	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2512	max. 0.17	0.30–0.60	0.04	0.045	4.50–5.25	.....	900	1650	air	830	1525	oil	595	1100	air	885	1625	pots	830	1525	oil	745	1375	oil	165	325
3115	0.10–0.20	0.30–0.60	0.04	0.045	1.00–1.50	0.45–0.75	925	1700	air	870	1600	oil	595	1000	air	900	1650	pots	845	1550	oil	760	1400	oil	165	325
3120	0.15–0.25	0.30–0.60	0.04	0.045	1.00–1.50	0.45–0.75	925	1700	air	870	1600	water	595	1100	air	900	1650	pots	845	1550	oil	{760 {782	1400 1440	water oil	165 165	325 325
3215	0.10–0.20	0.30–0.60	0.04	0.040	1.50–2.00	0.90–1.25	925	1700	air	845	1550	oil	620	1150	air	900	1650	pots	845	1550	oil	774	1425	oil	165	325
3220	0.15–0.25	0.30–0.60	0.04	0.040	1.50–2.00	0.90–1.25	925	1700	air	845	1550	oil	620	1150	air	900	1650	pots	845	1550	oil	760	1400	oil	175	350
3312	max. 0.17	0.30–0.60	0.04	0.040	3.25–3.75	1.25–1.75	900	1650	air	830	1525	oil	650	1200	air	885	1625	pots	855	1575	oil	760	1400	oil	190	375
3325	0.20–0.30	0.30–0.60	0.04	0.040	3.25–3.75	1.25–1.75	....	....	....	815	1500	oil	650	1200	air	885	1625	pots	855	1575	oil	760	1400	oil	190	375
3415	0.10–0.20	0.45–0.75	0.04	0.040	2.75–3.25	0.60–0.95	900	1650	air	845	1550	oil	620	1150	air	885	1625	pots	845	1550	oil	760	1400	oil	175	350
6120[a]	0.15–0.25	0.50–0.80	0.04	0.04	.....	0.80–1.10	900	1650	air	900	1650	oil	595	1100	air	899	1650	pots	885	1625	oil	802	1475	water	190	375

[a] This steel is a chromium-vanadium steel, the vanadium requirement being 0.15 per cent minimum with a desired content of 0.18 per cent.

11. The "depth of case" shall be taken to be the depth of the refined case to be observed with the naked eye after carburizing, hardening at the temperature giving maximum case refinement, and breaking for fracture. **Measurement.**

12. To obtain the best core condition, the part should be allowed to cool in the pots, outside the furnace, reheated and quenched from a temperature which will refine the core and break up any undesirable structures of cementite. This is called a regenerative quench. **Regenerative Quench.**

TABLE II.—COMMON DEFECTS IN CARBURIZED OBJECTS.

Defect	Cause	Indication	Correction
Depth of case and carbon content outside specified limits.	A. Carburizing temperature not correct.		
	A1. Furnace temperature uneven. Temperature of containers not uniform.	Results vary in the same furnace and from the same containers.	Redesign furnaces. Modify heating practice. Allow longer time for bringing furnaces to temperature.
	A2. Faulty pyrometer readings.	Entire furnace charges unsatisfactory.	Check pyrometer system.
	A3. Carburizing compound too weak or too strong.	Results from entire department vary from usual results.	Check carburizing compound before accepting shipment. Change time and temperature until desired results are obtained.
Soft spots obtained in hardening.	B1. Improper hardening. Temperature low or uneven.	File test.	Raise hardening temperature.
	B2. Improper quench.	File test.	Use faster quench, brine or spray.
	B3. Surface decarburized.	File test. Determine whether decarburization occurred in carburizing or hardening furnace.	Correct carburizing practice. Correct heating practice for hardening.
	B4. Low carbon content or uneven penetration.	As above for B3.	Correct carburizing practice. Try other compound. Check pyrometers.
Unsatisfactory fractures.	C1. Too high hardening temperatures.	Fracture test.	Decrease or adjust hardening temperature.
	C2. High surface carbon (freckled edges).	Fracture test.	Decrease hardening temperature. Use double quench with rather high temperature for regenerative quench. Use weaker compound.

13. The cooling of the carburized parts should take place in the containers, outside of the furnace. Where cost of production is vital, the parts may be quenched directly from the pot in either oil or water. **Cooling of Parts.**

14. In determining the depth of case desired, sufficient allowance must be made for the metal which will later be removed by grinding. A tempering operation will tend to eliminate the tendency for grinding cracks to form. **Grinding.**

15. The hardening temperature of the case is below the critical temperature of the core and the grain size produced in the core, by the carburizing temperature or regenerative quench, is not affected. The hardening temperature should be chosen as the temperature which gives the best fracture on several dummies or experimental pieces hardened from various temperatures. The figures given in Table I are the middle of the probable range of hardening temperatures. **Hardening.**

Distortion. 16. The tendency to distort may be avoided by a preliminary heat treatment, either before or after the rough machining operation. The method of carburizing must be studied and the subsequent hardening operations carried on with extreme care as to the heating and cooling cycles. In many cases, the regenerative quench must be omitted as the high temperature of this operation causes too much warping. When omitted, the carburizing temperature should be lowered about 38° C. (100° F.).

Tempering. 17. Tempering may be carried on at low temperatures, for the relief of strains, or at high temperatures, for the increase of toughness and uniformity without materially decreasing the hardness. An oil bath is preferable to an open furnace for temperatures up to 316° C. (600° F.). For simple carbon steels, a softening of the surface is found when the tempering temperature exceeds 190 to 204° C. (375 to 400° F.). For maximum hardness the temperature should be kept below this figure.

18. Table II shows in condensed form the most common defects in carburized work together with the possible causes and methods for their identification and correction.

STANDARD SPECIFICATIONS
FOR
WELDED WROUGHT-IRON PIPE[1]

Serial Designation: A 72 – 27

These specifications are issued under the fixed designation A 72; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1917; ADOPTED, 1918; REVISED, 1921, 1924, 1927.

Scope.

1. These specifications cover "standard weight," "extra strong" and "double extra strong" welded wrought-iron pipe.

Basis of Purchase.

2. All pipes to be used on locomotives and cars shall be of coiling or bending quality.

MANUFACTURE

Process.

3. (*a*) The iron shall be made from muck bars, made from all pig puddled iron, free from any admixture of iron scrap or steel.

(*b*) All pipe 3 in. or under in nominal diameter may be butt-welded, unless otherwise specified. All pipe over 3 in. in nominal diameter shall be lap-welded.

Definition of Scrap.

4. *Iron Scrap.*—This term applies only to foreign or bought scrap and does not include local mill products, free from foreign or bought scrap.

PHYSICAL PROPERTIES AND TESTS

Tension Tests.

5. (*a*) The material shall conform to the following minimum requirements as to tensile properties:

Tensile strength, lb. per sq. in.	40 000
Yield point, lb. per sq. in.	24 000
Elongation in 8 in., per cent	12

(*b*) The yield point shall be determined by the drop of the beam of the testing machine. The speed of the cross-head of the machine shall not exceed $\frac{3}{4}$ in. per minute.

Hydrostatic Tests.

6. All pipe shall be tested at the mill to the hydrostatic pressures specified in Table I.

Fracture Tests.

7. A section of pipe 6 in. in length shall be flattened until broken by repeated light blows of a hammer or by pressure; the fracture developed shall have a fibrous appearance.

Bend Test.

8. For pipe 2 in. or under in diameter, a sufficient length of coiling or bending pipe shall stand being bent cold through 90

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-2 on Wrought Iron.

deg., around a cylindrical mandrel the diameter of which is 15 times the nominal diameter of the pipe, without developing cracks at any portion and without opening the weld.

Micrographic Examination.

9. In case of doubt as to the presence of steel, the purchaser may, at his own expense, make micrographic examination and chemical analysis to assist in determining whether the material meets the requirements of Section 3 (*a*).

TABLE I.—HYDROSTATIC PRESSURES FOR WELDED WROUGHT-IRON PIPE.
(Pressures Expressed in Pounds per Square Inch.)

Size (Nominal Inside Diameter), in.	"Standard Weight" Pipe			"Extra Strong" Pipe			"Double Extra Strong" Pipe	
	Weight of Pipe per Linear Foot, Threaded and with Couplings, lb.	Butt-weld	Lap-weld	Weight of Pipe per Linear Foot, Plain Ends, lb.	Butt-weld	Lap-weld	Butt-weld	Lap-weld
$\frac{1}{8}$	.....	700	....	.....	700	....	....	....
$\frac{1}{4}$	.....	700	....	.....	700	....	....	....
$\frac{3}{8}$	.....	700	....	.....	700	....	....	....
$\frac{1}{2}$	.....	700	....	.....	700	....	700	....
$\frac{3}{4}$	.....	700	....	.....	700	....	700	....
1	.....	700	....	.....	700	....	700	....
$1\frac{1}{4}$	.....	700	1000	.....	1500	2500	2200	....
$1\frac{1}{2}$	.....	700	1000	.....	1500	2500	2200	3000
2	.....	700	1000	.....	1500	2500	2200	3000
$2\frac{1}{2}$	.....	800	1000	.....	1500	2000	2200	3000
3	.....	800	1000	.....	1500	2000	2200	3000
$3\frac{1}{2}$	.....	...	1000	.....	....	2000	....	2500
4	.....	...	1000	.....	....	2000	....	2500
5	.....	...	1000	.....	....	1800	....	2000
6	.....	...	1000	.....	....	1800	....	2000
8	25.00	...	800	.....	....	....	....	2000
8	28.81	...	1000	43.39	....	1500	....	....
10	32.00	...	600	.....	....	....	....	....
10	35.00	...	700	.....	....	....	....	....
10	41.13	...	900	54.74	....	1000	....	....
12	45.00	...	600	.....	....	....	....	....
12	50.71	...	800	65.42	....	1000	....	....

For pipes over 12 in. in inside diameter, the test pressures should be calculated by the formula $P=\frac{2\,St}{D}$ in which P = pressure in pounds per square inch; S = fiber stress = 12,000 lb. per sq. in.; t = thickness of wall in inches D = outside diameter in inches.

Test Specimens.

10. (*a*) Test specimens shall consist of sections cut from a pipe. They shall be smooth on the ends and free from burrs.

(*b*) Tension test specimens shall be longitudinal.

(*c*) All specimens shall be tested cold.

Number of Tests.

11. One of each of the tests specified in Sections 5, 7 and 8, may be made on a length in each lot of 500 or less, of each size. Each length shall be subjected to the hydrostatic test.

Retests.

12. If the results of the physical tests of any lot do not conform to the requirements specified in Sections 5, 7 and 8, retests of two

additional pipes shall be made, each of which shall conform to the requirements specified.

STANDARD WEIGHTS

13. (*a*) The standard weights for pipe of various inside diameters are given in Table II. **Standard Weights.**

(*b*) Nipples shall be cut from pipe of the same weight and quality as described in these specifications.

TABLE II.—STANDARD WEIGHTS AND DIMENSIONS OF WELDED WROUGHT-IRON PIPE.

Size (Nominal Inside Diameter), in.	Outside Diameter, in.	"Standard Weight" Pipe			"Extra Strong" Pipe		"Double Extra Strong" Pipe	
		Number of Threads, per Inch	Thickness, in.	Weight of Pipe per Linear Foot, Threaded and with Couplings, lb.	Thickness, in.	Weight of Pipe per Linear Foot, Plain Ends, lb.	Thickness, in.	Weight of Pipe per Linear Foot, Plain Ends, lb.
$\frac{1}{8}$.....	0.405	27	0.068	0.25	0.095	0.31	.....	.....
$\frac{1}{4}$.....	0.540	18	0.038	0.43	0.119	0.54	.....	.....
$\frac{3}{8}$.....	0.675	18	0.091	0.57	0.126	0.74	.....	.....
$\frac{1}{2}$.....	0.840	14	0.109	0.85	0.147	1.09	0.294	1.71
$\frac{3}{4}$.....	1.050	14	0.113	1.13	0.154	1.47	0.308	2.44
1.....	1.315	$11\frac{1}{2}$	0.133	1.68	0.179	2.17	0.358	3.66
$1\frac{1}{4}$.....	1.660	$11\frac{1}{2}$	0.140	2.28	0.191	3.00	0.382	5.21
$1\frac{1}{2}$.....	1.900	$11\frac{1}{2}$	0.145	2.73	0.200	3.63	0.400	6.41
2.....	2.375	$11\frac{1}{2}$	0.154	3.68	0.218	5.02	0.436	9.03
$2\frac{1}{2}$.....	2.875	8	0.203	5.82	0.276	7.66	0.552	13.70
3.....	3.500	8	0.216	7.62	0.300	10.25	0.600	18.583
$3\frac{1}{2}$.....	4.000	8	0.226	9.20	0.318	12.51	0.636	22.85
4.....	4.500	8	0.237	10.89	0.337	14.98	0.674	27.54
5.....	5.563	8	0.258	14.81	0.375	20.78	0.750	38.55
6.....	6.625	8	0.280	19.19	0.432	28.57	0.864	53.16
*8.....	8.625	8	0.277	25.00	.....	.....	0.875	72.42
8.....	8.625	8	0.322	28.81	0.500	43.39	.....	.....
*10.....	10.750	8	0.279	32.00	.....	.....	.....	.....
*10.....	10.750	8	0.307	35.00	.....	.....	.....	.....
10.....	10.750	8	0.365	41.13	0.500	54.74	.....	.....
*12.....	12.750	8	0.330	45.00	.....	.....	.....	.....
12.....	12.750	8	0.375	50.71	0.500	65.42	.....	.....

* Unless specifically stated on the order the lighter weights will not be furnished. Weights given in the table are for pipes up to and including 12 in. in nominal inside diameter, with threaded ends and couplings; sizes larger than those shown in the table are measured by the outside diameter and will be furnished with plain ends unless otherwise specified; for such sizes it will be necessary to accept Manufacturers' weights or calculate the weights on the basis of one cubic inch of steel weighing 0.2833 lb.

14. The weight of the pipe shall not vary more than 5 per cent from that specified in Table II. **Permissible Variations.**

15. Unless otherwise specified, pipe shall be furnished as to lengths in accordance with the following regular practice: **Lengths.**

(*a*) Standard weight pipe shall be in random lengths from 16 to 22 ft., but not more than 5 per cent of the total number of lengths may be "jointers," which are two pieces coupled together. When ordered with plain ends, 5 per cent may be in lengths of 12 to 16 ft.

(*b*) Extra strong pipe shall be in random lengths of 12 to 22 ft. and 5 per cent may be in lengths of 6 to 12 ft.

WORKMANSHIP AND FINISH

Workmanship.

16. (*a*) For pipe $1\frac{1}{2}$ in. or under in inside diameter, the outside diameter at any point shall vary not more than $\frac{1}{64}$ in. over nor more than $\frac{1}{32}$ in. under the standard size. For pipe 2 in. or over in inside diameter, the outside diameter shall vary not more than 1 per cent over or under the standard size.

17. Unless otherwise specified, pipe shall conform to the following regular practices:

Ends.

(*a*) Each end of standard weight pipe shall be threaded.

(*b*) Extra strong pipe shall be furnished with plain ends.

Threads.

(*c*) All threads shall be in accordance with the American Standard[1] and cut so as to make a tight joint when the pipe is tested at the mill to the specified internal hydrostatic pressure. The variation from the standard, when tested with the standard working gage, shall not exceed a maximum of one and one-half turns either way.

Couplings.

(*d*) Each length of threaded pipe shall be provided with one coupling, having clean-cut threads of such a pitch diameter as to make a tight joint. Couplings shall be of wrought iron.

Finish.

18. The finished pipe shall be reasonably straight and free from injurious defects. All burrs at the ends of the pipe shall be removed.

INSPECTION AND REJECTION

Inspection.

19. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the pipe ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the pipe are being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection.

20. Each length of pipe which develops injurious defects in shop working or application will be rejected, and the manufacturer shall be notified.

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[1] A complete description of the American Standard Pipe Thread is contained in the Pipe Thread Standard prepared under the sponsorship of the American Gas Association and the American Society of Mechanical Engineers and approved as American Standard by the American Engineering Standards Committee.

STANDARD SPECIFICATIONS
FOR
STAYBOLT, ENGINE-BOLT AND EXTRA-REFINED WROUGHT-IRON BARS[1]

Serial Designation: A 84 – 27

These specifications are issued under the fixed designation A 84; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ADOPTED, 1921; REVISED, 1924, 1927.

Scope.

1. These specifications cover three grades of bar iron:

Grade A—Staybolt iron.
Grade B—Engine-bolt iron.
Grade C—Extra-refined wrought-iron bars.

MANUFACTURE

Process.

2. *Grade A.*—The iron shall be rolled from a bloom, slab pile or box pile made wholly from reworked all-pig puddled iron or reworked knobbled charcoal iron. The original puddled or knobbled bar shall be twice piled and rerolled. All bars shall be the full length of the piles. The puddle mixture and the component parts of the bloom, slab pile or box pile shall be free from any admixture of iron scrap or steel.

Grades B and C.—The iron shall be made wholly from all-pig puddled iron and shall be free from any admixture of iron scrap or steel.

Definitions of Terms.

3. (*a*) *Bloom.*—A bloom is a solid mass of iron that has been hammered into a convenient size for rolling.

(*b*) *Slab Pile.*—A slab pile is built up wholly of flat bars of iron of the full length of the pile.

(*c*) *Box Pile.*—A box pile is a pile, the sides, top and bottom of which are formed by four flat bars and the interior of which consists of a number of small bars the full length of the pile.

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-2 on Wrought Iron.

These specifications are a consolidation of three specifications: Specifications for Staybolt Iron (former Serial Designation: A 39 - 18; adopted, 1910; revised 1912, 1914, 1918, 1921); Specifications for Engine-Bolt Iron (former Serial Designation: A 40 - 18; adopted, 1912; revised 1913, 1918, 1921); Specifications for Extra Refined Wrought-Iron Bars (former Serial Designation: A 79 - 19 T; issued as tentative, 1919; adopted in amended form, 1921).

(*d*) *Iron Scrap.*—This term applies only to foreign or bought scrap and does not include local mill products free from foreign or bought scrap.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

4. *Grade A.*—At the option of the purchaser and when so specified the iron shall conform to the following requirements as to chemical composition:

Manganese.....not over 0.10 per cent

Check Analysis.

5. (*a*) An analysis may be made by the purchaser from a broken test specimen representing each lot as specified in Section 11 (*a*). The chemical composition thus determined shall conform to the requirement specified in Section 4.

(*b*) Drillings for analysis shall be so taken as to represent the entire cross-section of the specimen.

PHYSICAL PROPERTIES AND TESTS

Tension Tests.

6. (*a*) The iron shall conform to the following requirements as to tensile properties:

		Grade A	Grade B	Grade C[e]
Tensile strength, lb. per sq. in.	$1\frac{1}{4}$ sq. in. or under in sectional area	48 000 – 52 000	49 000 – 53 000	48 000 – 54 000
	Over $1\frac{1}{4}$ sq. in. in sectional area	[a]	47 000 – 53 000	48 000 – 54 000[d]
Yield point, min., lb. per sq. in.	$1\frac{1}{4}$ sq. in. or under in sectional area	0.6 tens. str.	0.6 tens. str.	0.6 tens. str.
	Over $1\frac{1}{4}$ sq. in. to 4 sq. in., incl., in sectional area	....	0.55 "	0.55 "
	Over 4 sq. in. in sectional area	....	0.5 "	0.5 "
Elongation in 8 in., min., per cent.		30[b]	25	25[d]
Reduction of area, min., per cent.		48[c]	40	37[d]

[a] See Section 7 (*b*).
[b] See Section 7 (*a*).
[c] See Sections 7 (*b*) and (*c*).
[d] See Section 7 (*d*).

(*b*) The yield point shall be determined by the drop of the beam of the testing machine. The speed of the cross-head of the machine shall not exceed $\frac{3}{4}$ in. per minute.

Modifications in Tensile Properties.

7. (*a*) *Grade A.*—For bars $\frac{7}{8}$ in. or under in diameter, a reduction in the minimum elongation in 8 in. specified in Section 6 (*a*) shall be permitted, but in no case shall the elongation be less than 28 per cent.

(*b*) *Grade A.*—For bars over $1\frac{1}{4}$ sq. in. in sectional area, the following deductions from the minimum requirements specified in Section 6 (*a*) shall be made for each square inch of nominal section above $1\frac{1}{4}$ sq. in.:

Tensile strength	250 lb., but not under 46,000 lb. per sq. in.
Reduction of area	3 per cent, but not under 40 per cent

(*c*) *Grade A.*—For flats of all sizes, the minimum reduction of area shall be 40 per cent.

(*d*) *Grade C.*—For material over 4 sq. in. in sectional area, the following deductions from the minimum requirements specified in Section 6 (*a*) shall be made for each square inch of nominal section above 4 sq. in.:

Tensile strength	250 lb., but not under 46,000 lb. per sq. in.
Elongation	0.5 per cent, but not under 22 per cent
Reduction of area	1.0 " " " " 32 "

8. (*a*) Cold-Bend Tests: **Bend Tests.**

Grade A.—The test specimen shall withstand being bent cold through 180 deg. flat on itself in both directions, without fracture on the outside of the bent portions.

Grade B.—The test specimen shall withstand being bent cold through 180 deg. around a pin the diameter of which is equal to the diameter of the specimen, without fracture on the outside of the bent portion.

Grade C.—Cold-bent tests will be made only on bars having a nominal section area of 4 sq. in. or under, in which case the test specimen shall withstand being bent cold through 180 deg. without fracture on the outside of the bent portion, around a pin the diameter of which is equal to the thickness of the specimen.

(*b*) Hot-Bend Tests:

Grades B and C.—The test specimen when heated to a temperature between 1700 and 1800° F. shall withstand being bent through 180 deg. flat on itself without fracture on the outside of the bent portion.

(*c*) Nick-Bend Tests:

All Grades.—The test specimen when nicked 25 per cent around with a tool having a 60-deg. cutting edge, to a depth of not less than 8 nor more than 16 per cent of the diameter of the specimen, and broken, shall show a wholly fibrous fracture.

(*d*) Bend tests may be made by pressure or by blows.

9. The cross-section of the test specimen shall be ground or polished, and etched[1] for a sufficient period to develop the structure. This test shall show the material as follows: **Etch Tests.**

Grade A.—The material to have been rolled from a bloom, slab pile or box pile and to be uniform and free from steel.

[1] A solution of 10 per cent hydrochloric acid (sp. gr. 1.19), 30 per cent sulfuric acid (sp. gr. 1.84), and 60 per cent water; or 25 per cent nitric acid (sp. gr. 1.42), and 75 per cent water, is recommended for the etch test.

Grades B and C.—The material to be uniform and free from steel.

Test Specimens.

10. (*a*) Tension and bend test specimens shall be of the full section of material as rolled, if possible. Otherwise, the specimens shall be machined from the material as rolled; the axis of the specimen shall be located at any point midway between the center and surface of round bars, or midway between the center and edge of flat bars, and shall be parallel to the axis of the bar.

(*b*) Etch test specimens shall be of the full section of material as rolled.

Number of Tests.

11. (*a*) All bars of a given grade and size shall be piled separately, sorted in lots of 100 each. Two bars shall be selected at random from each lot or fraction thereof and tested as specified; but only one of these bars shall be tested as specified in Section 9.

TABLE I.—STANDARD LIMIT GAGES FOR ENGINE-BOLT IRON.

Nominal Diameter of Bars, in.	Large Size, +End, in.	Small Size, —End, in.	Total Variation, in.
1/4	0.2550	0.2450	0.010
5/16	0.3180	0.3070	0.011
3/8	0.3810	0.3690	0.012
7/16	0.4440	0.4310	0.013
1/2	0.5070	0.4930	0.014
9/16	0.5700	0.5550	0.015
5/8	0.6330	0.6170	0.016
3/4	0.7585	0.7415	0.017
7/8	0.8840	0.8660	0.018
1	1.0095	0.9905	0.019
1 1/8	1.1350	1.1150	0.020
1 1/4	1.2605	1.2395	0.021
1 3/8	1.3860	1.3640	0.022
1 1/2	1.5115	1.4885	0.023
1 5/8	1.6370	1.6130	0.024
1 3/4	1.7625	1.7375	0.025
1 7/8	1.8880	1.8620	0.026

Round bars 2 in. in diameter and over shall be rolled to nominal diameter.

(*b*) If any test specimen from the bars originally selected to represent a lot of material contains surface defects not visible before testing but visible after testing, or if a tension test specimen breaks outside the middle third of the gage length, the individual bar shall be rejected and one retest from a different bar will be allowed.

PERMISSIBLE VARIATIONS IN GAGE

Variations in Gage.

12. *Grade A.*—The bars shall be truly round within 0.01 in., and shall not be less than 0.005 in. over, nor more than 0.020 in. over the specified diameter.

Grade B.—The bars shall conform to the standard limit gages adopted by the Master Car Builders' Association, now the American Railway Association, Mechanical Division, as given in Table I.[1]

Grade C.—The width or thickness of bars shall vary not more than 2 per cent from that specified.

FINISH

13. The bars shall be smoothly rolled and free from slivers, depressions, crop ends, seams, and evidences of being burnt. **Finish.**

MARKING

14. The bars shall be stamped or otherwise marked as designated by the purchaser. **Marking.**

INSPECTION AND REJECTION

15. (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. Tests and inspection at the place of manufacture shall be made prior to shipment. **Inspection.**

(*b*) The purchaser may make the tests to govern the acceptance or rejection of material in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

(*c*) All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

16. (*a*) All bars of one size will be rejected if the test specimens representing that size do not conform to the requirements specified. **Rejection.**

(*b*) Unless otherwise specified, any rejection based on tests made in accordance with Section 15 (*b*) shall be reported within five working days from the receipt of samples.

(*c*) *Grade A.*—Bars which will not take a clean, sharp thread with dies in fair condition, or which develop defects in forging or machining, will be rejected, and the manufacturer shall be notified.

Grades B and C.—Bars which develop defects in forging or machining will be rejected, and the manufacturer shall be notified.

17. Samples tested in accordance with Section 15 (*b*), which represent rejected material, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time. **Rehearing.**

[1] Adopted by the Master Car Builders' Association in 1883 and revised in 1911. See *Manual of Standard and Recommended Practice*, American Railway Association, July, 1924, p. B-29.

STANDARD SPECIFICATIONS
FOR
HOLLOW ROLLED STAYBOLT IRON[1]

Serial Designation: A 86 – 27

These specifications are issued under the fixed designation A 86; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1921; ADOPTED IN AMENDED FORM, 1927.

MANUFACTURE

Process.

1. The iron shall be rolled from a bloom, slab pile or box pile, made wholly from reworked puddled pig iron or reworked knobbled charcoal iron. The puddle mixture and the component parts of the bloom, slab pile or box pile shall be free from any admixture of iron scrap or steel.

Definition of Terms.

2. (*a*) *Bloom.*—A bloom is a solid mass of iron that has been hammered into a convenient size for rolling.

(*b*) *Slab pile.*—A slab pile is built up wholly of flat bars of iron of the full length of the pile.

(*c*) *Box pile.*—A box pile is a pile, the sides, top and bottom of which are formed by four flat bars and the interior of which consists of a number of small bars the full length of the pile.

(*d*) *Iron Scrap.*—This term applies only to foreign or bought scrap and does not include local mill products free from foreign or bought scrap.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

3. The iron shall conform to the following requirement as to chemical composition:

Manganese	not over 0.10 per cent.

Check Analyses.

4. (*a*) An anlysis may be made by the purchaser from a broken tension test specimen representing each lot as specified in Section 10 (*a*). The chemical composition thus determined shall conform to the requirement specified in Section 3.

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-2 on Wrought Iron.

(*b*) Drillings for analysis shall be so taken as to represent the entire cross-section of the specimen.

PHYSICAL PROPERTIES AND TESTS.

5. (*a*) The iron shall conform to the following requirements as to tensile properties: **Tension Tests.**

Tensile strength, lb. per sq. in.	48 000 – 52 000
Yield point, min., lb. per sq. in.	0.6 tens. str.
Elongation, when measured in 8 in., min., per cent	28
Elongation, " " " 4 " " "	35
Reduction of area, min., per cent	42

(*b*) The yield point shall be determined by the drop of the beam of the testing machine. The speed of the cross-head of the machine shall not exceed $\frac{3}{4}$ in. per minute.

(*c*) In calculating the tensile strength and elastic limit, the area of a $\frac{7}{32}$-in. hole shall be deducted from the area of the bar, but the area of the hole shall be disregarded in calculating the reduction of area.

6. (*a*) The test specimen shall withstand being bent cold through 180 deg. flat on itself in both directions, without fracture on the outside of the bent portion. **Bend Tests.**

(*b*) Bend tests may be made by pressure or by blows.

7. A piece not less than 2 in. long shall be split open from end to end by driving a drift or wedge through the hole. The structure thus exhibited shall be free from signs of imperfect welding and the presence of slag or scale in the welds. **Splitting Tests.**

8. The cross-section of the test specimen shall be ground or polished, and etched[1] for a sufficient period to develop the structure. This test shall show the material to have been rolled from a bloom, slab pile or box pile, and to be free from steel. **Etch Tests.**

9. All test specimens shall be of the full section of material as rolled. **Test Specimens.**

10. (*a*) Bars of one size shall be sorted into lots of 1600 lineal feet. Two samples shall be selected at random from each lot and tested as specified in Sections 5, 6 and 7; but only one of these shall be tested as specified in Sections 4 and 8. **Number of Tests.**

(*b*) If any of the samples originally selected to represent a lot of material contains surface defects not visible before testing but visible after testing, or if a tension test specimen breaks outside the middle third of the gage length, the individual sample shall be rejected and one retest from a different bar or bolt will be allowed.

[1] A solution of 10 per cent hydrochloric acid (sp. gr. 1.19), 30 per cent sulfuric acid (sp. gr. 1.84), and 60 per cent water; or 25 per cent nitric acid (sp. gr. 1.42), and 75 per cent water, is recommended for the etch test.

PERMISSIBLE VARIATIONS IN GAGE

Permissible Variations. 11. The bars shall be truly round within 0.01 in. and shall be not less than 0.005 in. over, nor more than 0.020 in. over the specified diameter.

FINISH

Finish. 12. The bars shall be smoothly rolled and free from slivers, depressions, seams, crop ends, and evidences of being burnt.

MARKING

Marking. 13. The material shall be suitably marked for identification.

INSPECTION AND REJECTION

Inspection. 14. (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. Tests and inspection at the place of manufacture shall be made prior to shipment.

(*b*) The purchaser may make the tests to govern the acceptance or rejection of material in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

(*c*) All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection. 15. (*a*) If either of the samples selected to represent a lot does not conform to the requirements specified in Sections 3, 5, 6, 7, 8 and 9, the lot will be rejected.

(*b*) Unless otherwise specified, any rejection based on tests made in accordance with Section 14 (*b*) shall be reported within five working days from the receipt of samples.

(*c*) Bars which will not take a clean, sharp thread with dies in fair condition, or which develop defects in forging or machining, will be rejected, and the manufacturer shall be notified.

Rehearing. 16. Samples tested in accordance with Section 14 (*b*), which represent rejected material, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

STANDARD SPECIFICATIONS
FOR
REFINED WROUGHT-IRON BARS[1]

Serial Designation: A 41 – 18

These specifications are issued under the fixed designation A 41; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ADOPTED, 1912; REVISED, 1913, 1918.

These specifications were approved July 16, 1923, as "Tentative American Standard" by the American Engineering Standards Committee.

MANUFACTURE

Process.

1. Refined wrought-iron bars shall be made wholly from puddled iron, and may consist either of new muck-bar iron or a mixture of muck-bar iron and scrap, but shall be free from any admixture of steel.

PHYSICAL PROPERTIES AND TESTS

Tension Tests.

2. (*a*) The iron shall conform to the following minimum requirements as to tensile properties:

Tensile strength, lb. per sq. in. (See Sections 3 and 4)	48 000
Yield point, lb. per sq. in.	25 000
Elongation in 8 in., per cent (See Section 5)	22

(*b*) The yield point shall be determined by the drop of the beam of the testing machine. The speed of the cross-head of the machine shall not exceed $\frac{3}{4}$ in. per minute.

Modifications in Tensile Strength.

3. For material over 4 sq. in. in sectional area, a reduction of 500 lb. per sq. in. from the tensile strength specified in Section 2 will be permitted for each additional 2 sq. in., and a proportionate amount of reduction for fractional parts thereof; provided that the tensile strength shall not be less than 45,000 lb. per sq. in.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-2 on Wrought Iron.

Permissible Variations in Tensile Strength.

4. Twenty per cent of the test specimens representing one size may show tensile strengths 1000 lb. per sq. in. under or 5000 lb. per sq. in. over that specified in Sections 2 and 3; but no specimen shall show a tensile strength less than 45,000 lb. per sq. in.

Permissible Variations in Elongation.

5. Twenty per cent of the test specimens representing one size may show the following percentages of elongation in 8 in.:

ROUND BARS.

½ in. or over, tested as rolled	20 per cent
Under ½ in., " " "	16 "
Reduced by machining	18 "

FLAT BARS.

⅜ in. or over, tested as rolled	18 per cent
Under ⅜ in., " " "	16 "
Reduced by machining	16 "

Bend Tests.

6. (*a*) *Cold-bend Tests.*—Cold-bend tests will be made only on bars having a nominal sectional area of 4 sq. in. or under, in which case the test specimen shall stand being bent cold through 180 deg. without fracture on the outside of the bent portion, around a pin the diameter of which is equal to twice the diameter or thickness of the specimen.

(*b*) *Hot-bend Tests.*—The test specimen when heated to a temperature between 1700° and 1800° F. shall stand being bent through 180 deg. without fracture on the outside of the bent portion, as follows: For round bars under 2 sq. in. in section, flat on itself; for round bars 2 sq. in. or over in section and for all flat bars, around a pin the diameter of which is equal to the diameter or thickness of the specimen.

(*c*) *Nick-bend Tests.*—The test specimen, when nicked 25 per cent around for round bars, and along one side for flat bars, with a tool having a 60-deg. cutting edge, to a depth of not less than 8 nor more than 16 per cent of the diameter or thickness of the specimen, and broken, shall show not more than 10 per cent of the fractured surface to be crystallin.

(*d*) Bend tests may be made by pressure or by blows.

Etch Tests.

7. The cross-section of the test specimen shall be ground or polished, and etched[1] for a sufficient period to develop the structure. This test shall show the material to be free from steel.

Test Specimens.

8. (*a*) Tension and bend test specimens shall be of the full section of material as rolled, if possible. Otherwise, the specimens shall be machined from the material as rolled; the axis of the specimen shall be located at any point midway between the center and surface

[1] A solution of 10 per cent hydrochloric acid (sp. gr. 1.19), 30 per cent sulfuric acid (sp. gr. 1.84), and 60 per cent water; or 25 per cent nitric acid (sp. gr. 1.42), and 75 per cent water, is recommended for the etch test.

of round bars, or midway between the center and edge of flat bars, and shall be parallel to the axis of the bar.

(*b*) Etch test specimens shall be of the full section of material as rolled.

Number of Tests.

9. (*a*) All bars of a given size shall be piled separately sorted in lots of 100 each. One bar shall be selected at random from each 100 or fraction thereof and tested as specified.

(*b*) If any test specimen from the bar originally selected to represent a lot of material contains surface defects not visible before testing but visible after testing, or if a tension test specimen breaks outside the middle third of the gage length, the individual bar shall be rejected and one retest from a different bar will be allowed.

TABLE I.—STANDARD LIMIT GAGES.

Nominal Diameter of Bars, in.	Large Size, +End, in.	Small Size, −End, in.	Total Variation, in.
$\frac{1}{4}$	0.2550	0.2450	0.010
$\frac{5}{16}$	0.3180	0.3070	0.011
$\frac{3}{8}$	0.3810	0.3690	0.012
$\frac{7}{16}$	0.4440	0.4310	0.013
$\frac{1}{2}$	0.5070	0.4930	0.014
$\frac{9}{16}$	0.5700	0.5550	0.015
$\frac{5}{8}$	0.6330	0.6170	0.016
$\frac{3}{4}$	0.7585	0.7415	0.017
$\frac{7}{8}$	0.8840	0.8660	0.018
1	1.0095	0.9905	0.019
$1\frac{1}{8}$	1.1350	1.1150	0.020
$1\frac{1}{4}$	1.2605	1.2395	0.021
$1\frac{3}{8}$	1.3860	1.3640	0.022
$1\frac{1}{2}$	1.5115	1.4885	0.023
$1\frac{5}{8}$	1.6370	1.6130	0.024
$1\frac{3}{4}$	1.7625	1.7375	0.025
$1\frac{7}{8}$	1.8880	1.8620	0.026

Round bars 2 in. in diameter and over shall be rolled to nominal diameter.

PERMISSIBLE VARIATIONS IN GAGE

Variations in Gage.

10. (*a*) Round bars shall conform to the standard limit gages adopted by the Master Car Builders' Association, now the American Railway Association, Mechanical Division, as given in Table I.[1]

(*b*) The width or thickness of flat bars shall vary not more than 2 per cent from that specified.

FINISH

Finish.

11. The bars shall be smoothly rolled and free from slivers, depressions, crop ends, seams, and evidences of being burnt.

[1] Adopted by the Master Car Builders' Association in 1883 and revised in 1911. See *Manual of Standard and Recommended Practice*, American Railway Association, July, 1924, p. B-29.

INSPECTION AND REJECTION

Inspection.

12. (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. Tests and inspection at the place of manufacture shall be made prior to shipment.

(*b*) The purchaser may make the tests to govern the acceptance or rejection of material in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

(*c*) All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection.

13. (*a*) All bars of one size will be rejected if the test specimens representing that size do not conform to the requirements specified.

(*b*) Unless otherwise specified, any rejection based on tests made in accordance with Section 12 (*b*) shall be reported within five working days from the receipt of samples.

Rehearing.

14. Samples tested in accordance with Section 12 (*b*), which represent rejected material, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

STANDARD SPECIFICATIONS
FOR
COMMON IRON BARS[1]

Serial Designation: A 85 – 27

These specifications are issued under the fixed designation A 85; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1921; ADOPTED, 1924; REVISED, 1927.

MANUFACTURE

Process.

1. Common iron bars may be made from reworked iron scrap or a reworked mixture of iron and steel scrap, but shall be free from large areas of steel.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

2. The iron shall conform to the following requirements as to chemical composition:

Manganese	not over 0.30 per cent

Check Analysis.

3. (*a*) An analysis may be made by the purchaser from a broken tension test specimen representing each lot as specified in Section 11. The chemical composition thus determined shall conform to the requirement specified in Section 2.

(*b*) Drillings for analysis shall be so taken as to represent the entire cross-section of the specimen.

PHYSICAL PROPERTIES AND TESTS

Tension Tests.

4. (*a*) The iron shall conform to the following minimum requirements as to tensile properties:

Tensile strength, lb. per sq. in.	48 000
Yield point, lb. per sq. in.	25 000
Elongation in 8 in., per cent	22

(*b*) The yield point shall be determined by the drop of the beam of the testing machine. The speed of the cross-head of the machine shall not exceed $\frac{3}{4}$ in. per minute.

(*c*) *Appearance of Fracture.*—The broken ends of the tension test specimen shall show a uniform fibrous structure similar to that of wrought iron.

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-2 on Wrought Iron.

Modifications in Tensile Strength.

5. For material over 4 sq. in. in sectional area, a reduction of 250 lb. per sq. in. from the tensile strength specified in Section 4 will be permitted for each additional square inch, and a proportionate amount of reduction for fractional parts thereof; provided that the tensile strength shall not be less than 45,000 lb. per sq. in.

Permissible Variations in Tensile Strength.

6. Twenty per cent of the test specimens representing one size may show tensile strengths 1000 lb. per sq. in. under or 5000 lb. per sq. in. over that specified in Sections 4 and 5; but no specimen shall show a tensile strength less than 45,000 lb. per sq. in.

Permissible Variations in Elongation.

7. Twenty per cent of the test specimens representing one size may show the following percentages of elongation in 8 in.:

ROUND BARS.		
Tested as rolled	$\frac{1}{2}$ in. or over	20 per cent
	Under $\frac{1}{2}$ in	16 "
Reduced by machining		18 "
FLAT BARS.		
Tested as rolled	$\frac{3}{8}$ in. or over	18 per cent
	Under $\frac{3}{8}$ in	16 "
Reduced by machining		16 "

Bend Tests.

8. (*a*) *Cold-Bend Tests.*—Cold-bend tests will be made only on bars having a nominal area of 4 sq. in. or under, in which case the test specimen shall withstand being bent cold through 180 deg. without fracture on the outside of the bent portion, around a pin the diameter of which is equal to twice the diameter or thickness of the specimen.

(*b*) *Hot-Bend Tests.*—The test specimen when heated to a temperature between 1700 and 1800° F. shall withstand being bent through 180 deg. without fracture on the outside of the bent portion, as follows:—For round bars under 2 sq. in. in section, flat on itself; for round bars 2 sq. in. or over in sections and for all flat bars, around a pin the diameter of which is equal to the diameter or thickness of the specimen.

(*c*) *Nick-Bend Tests.*—The test specimen, when nicked 25 per cent around for round bars, and along one side for flat bars, with a tool having a 60-deg. cutting edge, to a depth of not less than 8 nor more than 16 per cent of the diameter or thickness of the specimen, and broken, shall show not more than 10 per cent of the fractured surface to be crystallin.

(*d*) Bend tests may be made by pressure or by blows.

Etch Tests.

9. The cross-section of the test specimen shall be ground or polished and etched[1] for a sufficient period to develop the structure.

[1] A solution of 10 per cent hydrochloric acid (sp. gr. 1.19), 30 per cent sulfuric acid (sp. gr. 1.84), and 60 per cent water; or 25 per cent nitric acid (sp. gr. 1.42), and 75 per cent water, is recommended for the etch test.

This test shall show the material to be of a uniform structure similar to wrought iron.

Test Specimens.

10. (*a*) Tension and bend test specimens shall be of the full section of material as rolled, if possible. Otherwise, the specimen shall be machined from the material as rolled; the axis of the specimens shall be located at any point midway between the center and surface of round bars, or midway between the center and edge of flat bars, and shall be parallel to the axis of the bar.

(*b*) Etch test specimens shall be of the full section of material as rolled.

Number of Tests.

11. (*a*) All bars of one size shall be piled separately. One bar shall be selected at random from each 100 or fraction thereof and tested as specified.

(*b*) If any test specimen from the bar originally selected to represent a lot of material contains surface defects not visible before testing but visible after testing, or if a tension test specimen breaks outside the middle third of the gage length, the individual bar shall be rejected and one retest from a different bar will be allowed.

PERMISSIBLE VARIATIONS IN GAGE

Permissible Variations.

12. (*a*) Round bars shall conform to the standard limit gages adopted by the Master Car Builders' Association, now the American Railway Association, Mechanical Division, as given in Table I.[1]

(*b*) The width or thickness of flat bars shall not vary more than 2 per cent from that specified.

FINISH

Finish.

13. The bars shall be smoothly rolled and free from slivers, depressions, seams, crop ends, and evidences of being burnt.

INSPECTION AND REJECTION

Inspection.

14. (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. Tests and inspection at the place of manufacture shall be made prior to shipment.

[1] Adopted by the Master Car Builders' Association in 1883 and revised in 1911. See *Manual of Standard and Recomemnded Practice*, American Railway Association, July, 1924, p. B-29.

(*b*) The purchaser may make the tests to govern the acceptance or rejection of material in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

(*c*) All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

TABLE I.—STANDARD LIMIT GAGE FOR COMMON IRON BARS.

Nominal Diameter of Bars, in.	Large Size, +End, in.	Small Size, −End, in.	Total Variation, in.
$\frac{1}{4}$	0.2550	0.2450	0.010
$\frac{5}{16}$	0.3180	0.3070	0.011
$\frac{3}{8}$	0.3810	0.3690	0.012
$\frac{7}{16}$	0.4440	0.4310	0.013
$\frac{1}{2}$	0.5070	0.4930	0.014
$\frac{9}{16}$	0.5700	0.5550	0.015
$\frac{5}{8}$	0.6330	0.6170	0.016
$\frac{3}{4}$	0.7585	0.7415	0.017
$\frac{7}{8}$	0.8840	0.8660	0.018
1	1.0095	0.9905	0.019
$1\frac{1}{8}$	1.1350	1.1150	0.020
$1\frac{1}{4}$	1.2605	1.2395	0.021
$1\frac{3}{8}$	1.3860	1.3640	0.022
$1\frac{1}{2}$	1.5115	1.4885	0.023
$1\frac{5}{8}$	1.6370	1.6130	0.024
$1\frac{3}{4}$	1.7625	1.7375	0.025
$1\frac{7}{8}$	1.8880	1.8620	0.026

Round bars 2 in. in diameter and over shall be rolled to nominal diameter.

Rejection. 15. (*a*) All bars of one size will be rejected if the test specimens representing that size do not conform to the requirements specified.

(*b*) Unless otherwise specified, any rejection based on tests made in accordance with Section 14 (*b*) shall be reported within five working days from the receipt of samples.

Rehearing. 16. Samples tested in accordance with Section 14 (*b*) which represent rejected material, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

STANDARD SPECIFICATIONS

FOR

WROUGHT-IRON PLATES[1]

Serial Designation: A 42 – 18

These specifications are issued under the fixed designation A 42; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ADOPTED, 1913; REVISED, 1918.

These specifications were approved July 16, 1923, as "Tentative American Standard" by the American Engineering Standards Committee.

Scope.

1. These specifications cover two classes of wrought-iron plates, as determined by the kind of material used in their manufacture, namely:

Class A, as defined in Section 2 (*b*);
Class B, as defined in Section 2 (*c*).

MANUFACTURE

Process.

2. (*a*) All plates shall be rolled from piles entirely free from any admixture of steel.

(*b*) Piles for Class A plates shall be made from puddle bars made wholly from pig iron and such scrap as emanates from rolling the plates.

(*c*) Piles for Class B plates shall be made from puddle bars made wholly from pig iron or from a mixture of pig iron and cast-iron scrap, together with wrought-iron scrap.

PHYSICAL PROPERTIES AND TESTS

Tension Tests.

3. (*a*) The plates shall conform to the following minimum requirements as to tensile properties:

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-2 on Wrought Iron.

Properties Considered.	Class A.		Class B.	
	6 in. to 24 in., incl., in width.	Over 24 in. to 90 in., incl., in width.	6 in. to 24 in., incl., in width.	Over 24 in. to 90 in., incl., in width.
Tensile strength, lb. per sq. in.	49 000	48 000	48 000	47 000
Yield point, lb. per sq. in.	26 000	26 000	26 000	26 000
Elongation in 8 in., per cent.	16	12	14	10

(*b*) The yield point shall be determined by the drop of the beam of the testing machine. The speed of the cross-head of the machine shall not exceed $\frac{3}{4}$ in. per minute.

Modifications in Elongation.

4. For plates under $\frac{7}{16}$ in. in thickness, a deduction of 1 from the percentages of elongation specified in Section 3 shall be made for each decrease of $\frac{1}{16}$ in. in thickness below $\frac{7}{16}$ in.

Bend Tests.

5. (*a*) *Cold-bend Tests.*—The test specimen shall bend cold through 90 deg. without fracture on the outside of the bent portion, as follows: For Class A plates, around a pin the diameter of which is equal to $1\frac{1}{2}$ times the thickness of the specimen; and for Class B plates, around a pin the diameter of which is equal to 3 times the thickness of the specimen.

(*b*) *Nick-bend Tests.*—The test specimen, when nicked on one side and broken, shall show for Class A plates a wholly fibrous fracture, and for Class B plates, not more than 10 per cent of the fractured surface to be crystallin.

Test Specimens.

6. Tension and bend test specimens shall be taken from the finished plates and shall be of the full thickness of plates as rolled. The longitudinal axis of the specimen shall be parallel to the direction in which the plates are rolled.

Number of Tests.

7. (*a*) One tension, one cold-bend and one nick-bend test shall be made for each variation in thickness of $\frac{1}{8}$ in. and not less than one test for every ten plates as rolled.

(*b*) If any test specimen fails to conform to the requirements specified by reason of an apparent local defect, a retest shall be made. If the retest also fails, the plates represented by such test will be rejected.

FINISH

Finish.

8. The plates shall be straight, smooth and free from cinder spots and holes, injurious flaws, buckles, blisters, seams and laminations.

MARKING

Marking.

9. The plates shall be stamped or otherwise marked as designated by the purchaser.

INSPECTION AND REJECTION

Inspection.

10. (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the plates ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the plates are being furnished in accordance with these specifications. Tests and inspection at the place of manufacture shall be made prior to shipment.

(*b*) The purchaser may make the tests to govern the acceptance or rejection of plates at his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

(*c*) All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection.

11. Unless otherwise specified, any rejection based on tests made in accordance with Section 10 (*b*) shall be reported within five working days from the receipt of samples.

Rehearing.

12. Samples tested in accordance with Section 10 (*b*), which represent rejected plates, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

STANDARD SPECIFICATIONS

FOR

WROUGHT-IRON ROLLED OR FORGED BLOOMS AND FORGINGS FOR LOCOMOTIVES AND CARS[1]

Serial Designation: A 73 – 24

These specifications are issued under the fixed designation A 73; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1917; ADOPTED IN AMENDED FORM, 1918; REVISED, 1924.

Scope.

1. These specifications cover two classes of wrought-iron blooms and forgings for locomotives and cars, as determined by the kind of material used in their manufacture: namely,

Class A, as defined in Section 2 (*a*);
Class B, as defined in Section 2 (*b*).

MANUFACTURE

Material.

2. (*a*) *Class A.*—Blooms and forgings of class A shall be made wholly from puddled pig iron. The puddle mixture and the component parts of the piles from which the blooms and forgings are made, shall be free from any admixture of iron scrap or steel. The term "iron scrap" applies only to foreign or bought scrap, and does not include the manufacturer's own scrap from the same product and of equal quality.

(*b*) *Class B.*—Blooms and forgings of class B shall be made from selected No. 1 wrought-iron scrap, or a mixture of such scrap and the puddled iron described in Paragraph (*a*).

Process.

3. Cross piling will not be permitted in either class of forging. In the final pile for the bloom or forging, all bars and slabs shall be of the full length of the pile.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

4. The iron shall conform to the following requirement as to chemical composition:

	Class A	Class B
Manganese, max., per cent	0.07	0.15

[1]Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-2 on Wrought Iron.

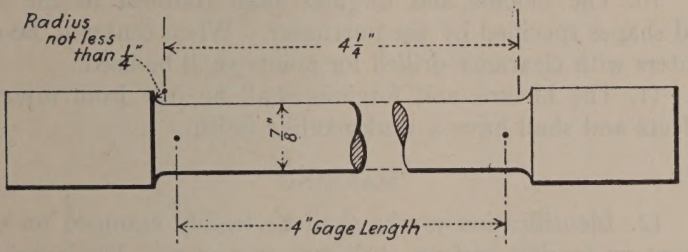
5. (*a*) An analysis may be made by the purchaser from each specimen used for the tension test. The chemical composition thus determined shall conform to the requirement specified in Section 4. **Check Analyses.**

(*b*) Drillings or chips for analysis shall be so taken as to represent the full cross-section of the specimen.

PHYSICAL PROPERTIES AND TESTS

6. (*a*) The iron shall conform to the following minimum requirements as to tensile properties: **Tension Tests.**

	Blooms	Forgings Classes A and B
Tensile strength, lb. per sq. in..	45 000	45 000
Yield point, lb. per sq. in.....	0.5 tens. str.	0.5 tens. str.
Elongation in 4 in., per cent...	22	24
Reduction of area, per cent....	30	33



Note: — The Gage Length, Parallel Portions and Fillets shall be as Shown, but the Ends may be of any Form which will Fit the Holders of the Testing Machine.

FIG. 1.

(*b*) The fracture shall be free from crystallization.

(*c*) The yield point shall be determined by the drop of the beam of the testing machine. The speed of the cross-head of the machine shall not exceed $\frac{3}{8}$ in. per minute.

7. The entire cross-section of the prolongation of the bloom or forging shall be ground or polished, and shall show no seams or flaws of injurious character. It shall then be etched[1] and, in class A blooms or forgings, shall show freedom from steel. **Etch Tests.**

8. (*a*) Tension test specimens shall be taken from a full-size prolongation of the bloom or forging. The axis of the specimen shall be located at any point midway between the center **Tension Test Specimens.**

[1] A solution of 10 per cent hydrochloric acid (sp. gr. 1.19), 30 per cent sulfuric acid (sp. gr. 1.84), and 60 per cent water; or 25 per cent nitric acid (sp. gr. 1.42), and 75 per cent water, is recommended for the etch test.

and surface of the bloom or forging, and shall be parallel to the axis of the bloom or forging.

(*b*) The specimens shall conform to the dimensions shown in Fig. 1. The ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial.

Number of Tests.

9. Unless otherwise specified, one test shall be made from each lot of 10 blooms or less and from each lot of 4000 lb. or less of forgings. These tests shall be made on prolongations the full size of the blooms or the largest section of the forging, and for test purposes, prolongations shall be furnished on at least 20 per cent of the blooms or forgings. In the case of small forgings, one forging may be used for test purposes, in which case one test will represent not more than 100 forgings.

WORKMANSHIP AND FINISH

Workmanship.

10. The blooms and forgings shall conform to the sizes and shapes specified by the purchaser. When centered, 60-deg. centers with clearance drilled for points shall be used.

Finish.

11. The blooms and forgings shall be free from injurious defects and shall have a workmanlike finish.

MARKING

Marking.

12. Identification marks shall be legibly stamped on each bloom or forging and on each test specimen. The purchaser shall indicate the location of such identification marks.

INSPECTION AND REJECTION

Inspection.

13. (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the blooms or forgings ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the blooms or forgings are being furnished in accordance with these specifications. Tests and inspection at the place of manufacture shall be made prior to shipment.

(*b*) The purchaser may make the tests to govern the acceptance or rejection of the blooms or forgings in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

(*c*) Tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

14. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 13 (*b*) shall be reported within five working days from the receipt of samples. **Rejection.**

(*b*) Blooms and forgings which show injurious defects while being finished by the purchaser will be rejected, and the manufacturer shall be notified.

15. Samples tested in accordance with Section 13 (*b*), which represent rejected blooms or forgings, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests the manufacturer may make claim for a rehearing within that time. **Rehearing.**

STANDARD SPECIFICATIONS
FOR
IRON AND STEEL CHAIN[1]

Serial Designation: A 56 – 24

These specifications are issued under the fixed designation A 56; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ADOPTED, 1915; REVISED, 1918; RESUBMITTED AS TENTATIVE, 1921; ADOPTED IN AMENDED FORM, 1924.

Scope.

1. (*a*) These specifications cover five classes of iron and steel chain.

(*b*) The purposes for which these classes are generally used and the trade designations are as follows:

Class AA, for slings, cranes, hoists, steam shovels, and marine uses, and where an all-iron chain is desired.

Class A, for slings, cranes, hoists, steam shovels and marine uses where a high quality chain is desired and sold under the trade designation "Dredge Chain."

Class BBB, for ordinary slings and hoists.

Class BB, for railroads and construction work.

Class Proof Coil, for railroad cars, construction and forestry work.

MATERIAL AND MANUFACTURE

Material.

2. The material entering into the five classes of chain shall be as follows:

Class AA.—Wrought-iron chain. The wrought iron shall be made wholly from all pig puddled iron free from any admixture of iron scrap or steel.

NOTE.—The term "iron scrap" applies only to foreign or bought scrap and does not include local mill products free from foreign or bought scrap.

Class A.—Wrought-iron chain. The wrought iron shall be made from all pig puddled iron or a mixture of puddled iron and reworked scrap.

Class BBB.—Wrought-iron or open-hearth steel chain. The wrought iron may be made from a mixture of all pig puddled iron and reworked scrap or from all reworked scrap.

[1] Under the standardization procedure of the Society, these specifications are under the joint jurisdiction of the A.S.T.M. Committees A-1 on Steel and A-2 on Wrought Iron.

Class BB.—Wrought-iron or open-hearth steel chain. The wrought iron may be made from all reworked scrap.

Class Proof Coil.—Wrought-iron or open-hearth steel chain. The wrought iron may be made from all reworked scrap.

NOTE.—The term "reworked scrap" applies to steel and iron scrap, or a mixture of both.

Welding.

3. Classes AA and A chain shall be lap-fire-welded. Unless otherwise specified, Classes BBB, BB and Proof Coil, may be made by either fire or electric welding process.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

4. The wrought iron and steel of the respective classes of chain shall conform to the following requirements as to chemical composition:

	Iron		Steel
	Class AA	Class A	Classes BBB, BB, and Proof Coil
Manganese, maximum, per cent.....	0.10	0.20	....
Phosphorus, " "	....	....	0.04
Sulfur, " "	....	....	0.04

Check Analyses.

5. (*a*) Analyses may be made by the purchaser from the bars or from the finished chain. The chemical composition thus determined shall conform to the requirements specified in Section 4.

(*b*) Drillings for analysis shall be taken with a drill the diameter of which is approximately one-half the diameter of the bar from which the drillings are taken, and cuttings shall be taken through the bar from surface to surface.

PHYSICAL PROPERTIES AND TESTS

Proof Tests.

6. (*a*) All chain shall be proof tested by subjecting it to the loads shown in Table I, and when so tested it shall stand these loads without showing any defects.

(*b*) When requested, the manufacturer shall furnish a certificate of proof test to the purchaser or his representative.

Tension Tests.

7. (*a*) Samples from finished chain shall conform to the minimum requirements as to tensile strength specified in Table II.

(*b*) The elongation, determined in a gage length of from 12 to 18 in. to the nearest link, shall conform to the following minimum requirements for the respective classes:

Classes AA and A.....	15 per cent
Class BBB.....	15 " "
Class BB.....	12 " "
Class Proof Coil.....	10 " "

TABLE I.—PROOF TESTS.

Nominal Size of Chain Bar, in.	Proof Test Loads, lb.			
	Class AA "W. I." and Class A "Dredge," Iron	Class BBB, Iron or Steel	Class BB, Iron or Steel	Class Proof Coil, Iron or Steel
1/4	....	2 250	2 025	1 700
5/16	....	3 400	3 050	2 650
3/8	4 350	4 650	4 175	3 850
7/16	5 950	6 250	5 625	5 250
1/2	7 800	8 250	7 425	6 850
9/16	9 900	10 250	9 225	8 650
5/8	12 150	12 500	11 250	10 700
3/4	17 500	17 700	15 900	15 350
7/8	23 800	24 000	21 600	20 900
1	31 100	31 000	27 900	27 350
1 1/8	39 350	39 000	35 100	....
1 1/4	48 600	48 000	43 200	....
1 3/8	58 800	....	....	....
1 1/2	70 000	....	....	....
1 5/8	81 500	....	....	....
1 3/4	93 900	....	....	....
1 7/8	107 100	....	....	....
2	121 150	....	....	....

TABLE II.—TENSILE STRENGTH.

Nominal Size of Chain Bar, in.	Breaking Load, lb.			
	Class AA "W. I." and Class A "Dredge," Iron	Class BBB, Iron or Steel	Class BB, Iron or Steel	Class Proof Coil, Iron or Steel
1/4	....	4 500	4 050	3 400
5/16	....	6 800	6 100	5 300
3/8	8 700	9 300	8 350	7 700
7/16	11 900	12 500	11 250	10 500
1/2	15 600	16 500	14 850	13 700
9/16	19 800	20 500	18 450	17 300
5/8	24 300	25 000	22 500	21 400
3/4	35 000	35 400	31 800	30 700
7/8	47 600	48 000	43 200	41 800
1	62 200	62 000	55 800	54 700
1 1/8	78 700	78 000	70 200	....
1 1/4	97 200	96 000	86 400	....
1 3/8	117 600	....	....	....
1 1/2	140 000	....	....	....
1 5/8	163 000	....	....	....
1 3/4	187 800	....	....	....
1 7/8	214 200	....	....	....
2	242 300	....	....	....

8. Tension test specimens shall consist of a length not less than 2 ft., cut from the finished chain. **Test Specimens.**

9. One tension test shall be made to represent each lot of 200 ft. of chain or fraction thereof ordered. **Number of Tests.**

TABLE III.—NOMINAL WEIGHTS AND DIMENSIONS.

Nominal Size of Chain Bar, in.	Actual Size of Material, in.	Nominal Length of 100 Links, in.			Nominal Weight per 100 ft., lb.		
		Class BBB	Class BB	Class Proof Coil	Class BBB	Class BB	Class Proof Coil
1/4	9/32	86	91	100	78	75	70
5/16	11/32	100	103	111	115	112	105
3/8	13/32	109	116	123	166	162	158
7/16	15/32	122	130	138	220	215	210
1/2	17/32	134	141	150	275	270	265
9/16	19/32	156	163	175	350	345	335
5/8	21/32	169	175	188	430	425	410
3/4	25/32	188	200	213	615	605	580
7/8	29/32	225	238	250	820	815	780
1	33/32	256	263	275	1 045	1 030	1 000
1 1/8	37/32	288	300	...	1 310	1 300	...
1 1/4	41/32	306	313	...	1 600	1 585	...

Nominal Size of Chain Bar, in	Nominal Dimensions of Links, in.											
	Class BBB				Class BB				Class Proof Coil			
	Outside		Inside		Outside		Inside		Outside		Inside	
	Length	Width	Length	Width	Length	Width	Length	Width	Length	Width	Length	Width
1/4	1 27/64	1	55/64	7/16	1 15/32	1	29/32	7/16	1 9/16	1 1/16	1	1/2
5/16	1 11/16	1 3/16	1	1/2	1 23/32	1 3/16	1 1/32	1/2	1 51/64	1 3/16	1 7/64	1/2
3/8	1 29/32	1 7/16	1 3/32	5/8	1 31/32	1 7/16	1 5/32	5/8	2 3/64	1 7/16	1 15/64	5/8
7/16	2 5/32	1 5/8	1 7/32	11/16	2 15/64	1 5/8	1 19/64	11/16	2 5/16	1 11/16	1 3/8	3/4
1/2	2 13/32	1 13/16	1 11/32	3/4	2 15/32	1 13/16	1 13/32	3/4	2 9/16	1 7/8	1 1/2	13/16
9/16	2 3/4	1 15/16	1 9/16	3/4	2 13/16	1 15/16	1 5/8	3/4	2 15/16	2 1/16	1 3/4	7/8
5/8	3	2 1/16	1 11/16	7/8	3 1/16	2 1/16	1 3/4	7/8	3 3/16	2 5/16	1 7/8	1
3/4	3 7/16	2 9/16	1 7/8	1	3 9/16	2 9/16	2	1	3 11/16	2 11/16	2 1/8	1 1/8
7/8	4 1/16	3 1/16	2 1/4	1 1/4	4 3/16	3 1/16	2 3/8	1 1/4	4 5/16	3 3/16	2 1/2	1 3/8
1	4 5/8	3 7/16	2 9/16	1 3/8	4 11/16	3 7/16	2 5/8	1 3/8	4 13/16	3 9/16	2 3/4	1 1/2
1 1/8	5 3/16	3 15/16	2 7/8	1 5/8	5 5/16	4	3	1 11/16	...	...	...	...
1 1/4	5 5/8	4 5/16	3 1/16	1 3/4	5 11/16	4 5/16	3 1/8	1 3/4	...	...	...	...

NOTE.—Classes AA and A being ordered to special dimensions, the weight and dimensions are not provided except that when crane chain is specified under Class A, the length of 100 links and the nominal weight per 100 ft. shall be in accordance with Class BBB in Table III.

10. If the tension test fails to conform to the requirements specified in Section 7, two additional tension tests may be made from the same lot, each of which shall meet the requirements of Section 7. **Retests.**

11. *Class AA.*—The cross-section of the test specimen shall be **Etch Tests.**

ground or polished, and etched[1] for a sufficient period to develop the structure. The test shall show the material to be free from steel.

STANDARD WEIGHTS AND DIMENSIONS

Nominal Weights and Lengths.

12. (*a*) The nominal weights of 100 ft., nominal lengths of 100 links and nominal dimensions of links for chain of various sizes are given in Table III.

(*b*) The weights and lengths of 100 links of chain shall not vary more than 4 per cent over nor more than 4 per cent under the nominal weight and lengths specified in Table III. Excess weight over the permissible variations of 4 per cent may be cause for rejection. All chain accepted shall be paid for at actual weight.

(*c*) The length shall be measured after the chain has been proof tested, and shall be measured to the inside of the end links.

(*d*) In determining the length of the chain, a load not exceeding 10 per cent of the proof load specified in Table I shall be applied to take up the slack.

WORKMANSHIP AND FINISH

Workmanship and Finish.

13. (*a*) The chain shall be free from injurious defects and shall have a workmanlike finish. The diameter of the bar in all chain shall not be less than the nominal size in the body and welds, and unless otherwise specified, the weld shall not exceed the diameter of the bar more than 25 per cent.

(*b*) Prior to testing and inspection the chain shall be free from paint or other coating which would tend to conceal defects.

INSPECTION AND REJECTION

Inspection.

14. (*a*) The inspector representing the purchaser shall have free entry at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the chain ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the chain is being furnished in accordance with these specifications.

(*b*) Unless otherwise specified, all tests and inspection shall be made at the place of manufacture; but when specified by the purchaser he may make the tests and inspection to govern the acceptance or rejection of the chain at his own laboratory or elsewhere at his own expense.

[1] A solution of 10 per cent hydrochloric acid (sp. gr. 1.19), 30 per cent sulfuric acid (sp. gr. 1.84), and 60 per cent water; or 25 per cent nitric acid (sp. gr. 1.42) and 75 per cent water, is recommended for the etch test.

(*c*) Tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

15. Unless otherwise specified, any rejection based on tests made in accordance with Section 14 (*b*) shall be reported within five working days from receipt of samples. Rejection.

16. Samples tested in accordance with Section 14 (*b*), which represent rejected chain, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time. Rehearing.

STANDARD DEFINITIONS
OF
TERMS RELATING TO WROUGHT-IRON SPECIFICATIONS[1]

Serial Designation: A 81 – 27

These definitions are issued under the fixed designation A 81; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1920; ADOPTED, 1921; REVISED, 1927.

Puddling.—The process of making wrought iron by oxidizing and removing most of the silicon, carbon, manganese and phosphorus contained in pig iron in a reverberatory furnace. "Puddling" formerly was applied only to the practice of employing refined pig iron, and "Pig Boiling" was the name applied when unrefined pig iron was used, but now this distinction is not generally made as the pig iron is seldom refined. Puddling as practiced to-day is really pig boiling.

Bushelling.—The process of heating to a welding heat in a reverberatory furnace, miscellaneous iron, steel or a mixture of iron and steel scrap cut into small pieces.

Fagoting.—The making of a "Fagot" or "Box" consisting of sides and bottom made of muck or scrap bar, the interior of which is filled with miscellaneous small iron scrap or a mixture of small iron and steel scrap.

Muck Bar or Puddled Bar.—Bar rolled from puddled balls, made wholly from puddled pig iron.

Common Iron.—Iron made from rerolled scrap, no attempt being made to separate the iron and steel scrap.

Refined Bar Iron or Refined Wrought-Iron Bars.—Iron rolled from muck bar pile, the muck bar being rolled from all puddled pig iron or rolled from a box pile of muck bars and wrought scrap free from steel; the bars to be the full length of the pile.

Double Refined Iron.—Iron made by cutting refined iron bars, piling them in either a slab pile or box pile, heating them and rerolling into finished bars.

[1] Under the standardization procedure of the Society, these definitions are under the jurisdiction of the A.S.T.M. Committee A-2 on Wrought Iron.

STANDARD SPECIFICATIONS
FOR
FOUNDRY PIG IRON[1]

Serial Designation: A 43 – 24

These specifications are issued under the fixed designation A 43; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ADOPTED, 1904; REVISED, 1909, 1924.

MANUFACTURE

Manufacture.

1. The pig iron shall be clean foundry pig iron, as free as possible from an excessive amount of dross and sand, and may be either sand or machine cast.

CHEMICAL PROPERTIES

Chemical Properties.

2. (*a*) The pig iron shall conform to the chemical requirements specified by the purchaser at the time of purchase, with the following permissible variations from the specified percentages in the case of pig iron intended for the manufacture of gray-iron castings:

ELEMENT	VARIATION FROM SPECIFIED PERCENTAGE
Silicon	0.25 per cent above and below
Manganese	0.20 " " " " "
Phosphorus	0.15 " " " " "
Sulfur	not over specified percentage
Total carbon	not less than " "

(*b*) In the case of pig iron for making steel and malleable iron castings, a maximum percentage of phosphorus and either a maximum or minimum percentage of manganese may be specified.

SAMPLING AND ANALYSIS

Sampling.

3. (*a*) In sampling, each carload, or its equivalent, shall be considered as a unit.

(*b*) One pig shall be taken to every four tons in the car, and they shall be so chosen from different parts of the car as to secure, as nearly as possible, a sample representing the average quality of the iron.

(*c*) The pigs thus taken shall be sampled by drilling so as to fairly represent the composition of the pigs as cast.

(*d*) An equal weight of the drillings from each pig shall be thoroughly mixed to make up the sample for analysis.

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-3 on Cast Iron.

Analysis. 4. It is recommended that analyses be made in accordance with the Standard Methods of Sampling and Chemical Analysis of Pig and Cast Iron (Serial Designation: A 64) of the American Society for Testing Materials.[1]

INSPECTION AND REJECTION

Inspection. 5. In case of dispute, the sampling and chemical analysis shall be made in accordance with the Standard Methods of Sampling and Chemical Analysis of Pig and Cast Iron (Serial Designation: A 64) of the American Society for Testing Materials[1] by an independent chemist, mutually agreed upon, if practicable, at the time the contract is made, whose decision shall be final. The cost of such re-sampling and re-analysis shall be borne by the party in error.

Rejection. 6. All pig iron which fails to conform to these specifications shall be subject to rejection.

[1] See p. 448.

APPENDIX

(This appendix is merely a recommendation and is not a part of the specifications.)

In using these specifications it is not advised that all five elements be specified in all contracts for pig iron, but it is recommended that, when these elements are specified, the following percentages be used, and for convenience the accompanying code is endorsed:

SILICON	
PER CENT	CODE
1.00	La
1.50	Le
2.00	Li
2.50	Lo
3.00	Lu
3.50	Ly
3.75	Ld
4.00	Lf

(0.25 allowed either way)

SULFUR	
PER CENT	CODE
0.04	Sa
0.05	Se
0.06	Si
0.07	So
0.08	Su
0.09	Sy
0.10	Sh

(Maximum)

TOTAL CARBON	
PER CENT	CODE
3.00	Ca
3.20	Ce
3.40	Ci
3.60	Co
3.80	Cu
4.00	Cy

(Minimum)

MANGANESE	
PER CENT	CODE
0.20	Ma
0.40	Me
0.60	Mi
0.80	Mo
1.00	Mu
1.25	My
1.50	Mh

(0.20 allowed either way)

PHOSPHORUS	
PER CENT	CODE
0.20	Pa
0.40	Pe
0.60	Pi
0.80	Po
1.00	Pu
1.25	Py
1.50	Ph
1.75	Pd
2.00	Pf

(0.15 allowed either way)

Illustration of the use of above coding: The word Li-se-ca-mo-pi indicates

SILICON	SULFUR	CARBON	MANGANESE	PHOSPHORUS
2.00	0.05	3.00	0.80	0.60

with variations as allowed.

Percentages of any element specified half way between the above shall be designated by the addition of the letter *X* to the next lower symbol.

Example.—PeX indicates Phosphorus 0.50, with allowed variations (0.15) either way.

STANDARD SPECIFICATIONS
FOR
CAST-IRON PIPE AND SPECIAL CASTINGS[1]

Serial Designation: A 44 – 04

These specifications are issued under the fixed designation A 44; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ADOPTED, 1904.

DESCRIPTION OF PIPES.

SECTION 1. The pipes shall be made with hub and spigot joints, and shall accurately conform to the dimensions given in Tables I and II. They shall be straight and shall be true circles in section, with their inner and outer surfaces concentric, and shall be of the specified dimensions in outside diameter. They shall be at least 12 ft. in length, exclusive of socket. For pipes of each size from 4 in. to 24 in., inclusive, there shall be two standards of outside diameter, and for pipes from 30 in. to 60 in., inclusive, there shall be four standards of outside diameter, as shown by Table I.

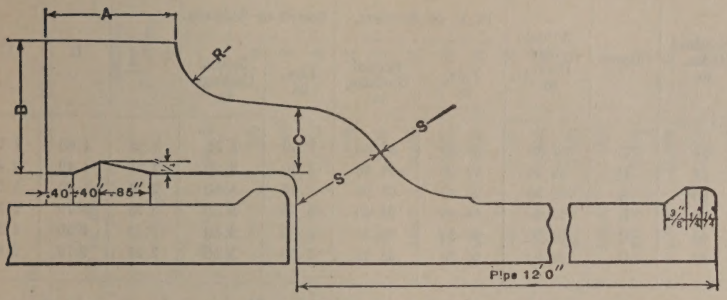
All pipes having the same outside diameter shall have the same inside diameter at both ends. The inside diameter of the lighter pipes of each standard outside diameter shall be gradually increased for a distance of about 6 in. from each end of the pipe so as to obtain the required standard thickness and weight for each size and class of pipe.

Pipes whose standard thickness and weight are intermediate between the classes in Table II shall be made of the same outside diameter as the next heavier class. Pipes whose standard thickness and weight are less than shown by Table II shall be made of the same outside diameter as the Class A pipes, and pipes whose thickness and weight are more than shown by Table II shall be made of the same outside diameter as the Class D pipes.

For pipes 4 in. to 12 in., inclusive, one class of special castings shall be furnished, made from Class D pattern. Those

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-3 on Cast Iron.

TABLE I.—GENERAL DIMENSIONS OF PIPES.



Nominal Diam., in.	Classes.	Actual Outside Diam., in.	Diam. of Sockets.		Depth of Sockets.		A	B	C
			Pipe, in.	Special Castings, in.	Pipe, in.	Special Castings, in.			
4	A—B	4.80	5.60	5.70	3.50	4.00	1.5	1.30	0.65
4	C—D	5.00	5.80	5.70	3.50	4.00	1.5	1.30	0.65
6	A—B	6.90	7.70	7.80	3.50	4.00	1.5	1.40	0.70
6	C—D	7.10	7.90	7.80	3.50	4.00	1.5	1.40	0.70
8		9.05	9.85	10.00	4.00	4.00	1.5	1.50	0.75
8	C—D	9.30	10.10	10.00	4.00	4.00	1.5	1.50	0.75
10	A—B	11.10	11.90	12.10	4.00	4.00	1.5	1.50	0.75
10	C—D	11.40	12.20	12.10	4.00	4.00	1.5	1.60	0.80
12	A—B	13.20	14.00	14.20	4.00	4.00	1.5	1.60	0.80
12	C—D	13.50	14.30	14.20	4.00	4.00	1.5	1.70	0.85
14	A—B	15.30	16.10	16.10	4.00	4.00	1.5	1.70	0.85
14	C—D	15.65	16.45	16.45	4.00	4.00	1.5	1.80	0.90
16	A—B	17.40	18.40	18.40	4.00	4.00	1.75	1.80	0.90
16	C—	17.80	18.80	18.80	4.00	4.00	1.75	1.90	1.00
18	A—B	19.50	20.50	20.50	4.00	4.00	1.75	1.90	0.95
18	C—D	19.92	20.92	20.92	4.00	4.00	1.75	2.10	1.05
20	A—B	21.60	22.60	22.60	4.00	4.00	1.75	2.00	1.00
20	C—D	22.06	23.06	23.06	4.00	4.00	1.75	2.30	1.15
24	A—B	25.80	26.80	26.80	4.00	4.00	2.00	2.10	1.05
24	C—D	26.32	27.32	27.32	4.00	4.00	2.00	2.50	1.25
30	A	31.74	32.74	32.74	4.50	4.50	2.00	2.50	1.15
30	B	32.00	33.00	33.00	4.50	4.50	2.00	2.30	1.15
30	C	32.40	33.40	33.40	4.50	4.50	2.00	2.60	1.32
30	D	32.74	33.74	33.74	4.50	4.50	2.00	3.00	1.50
36	A	37.96	38.96	38.96	4.50	4.50	2.00	2.50	1.25
36	B	38.30	39.30	39.30	4.50	4.50	2.00	2.80	1.40
36	C	38.70	39.70	39.70	4.50	4.50	2.00	3.10	1.60
36	D	39.16	40.16	40.16	4.50	4.50	2.00	3.40	1.80
42	A	44.20	45.20	45.20	5.00	5.00	2.00	2.80	1.40
42	B	44.55	45.50	45.50	5.00	5.00	2.00	3.00	1.50
42	C	45.10	46.10	46.10	5.00	5.00	2.00	3.40	1.75
42	D	45.58	46.58	46 58	5.00	5.00	2.00	3.80	1.95
48	A	50.50	51.50	51 50	5.00	5.00	2.00	3.00	1.50
48	B	50.80	51.80	51.80	5.00	5.00	2.00	3.30	1.65
48	C	51.40	52.40	52.40	5.00	5.0	2.00	3.80	1.95
48	D	51.98	52.98	52.98	5.00	5.0	2.00	4.20	2.20
54	A	56.66	57.66	57.66	5.50	5.50	2.25	3.20	1.60
54	B	57.10	58.10	58.10	5.50	5.5	2.25	3.60	1.80

TABLE I.—(CONTINUED.)

Nominal Diam., in.	Classes.	Actual Outside Diam., in.	Diam. of Sockets.		Depth of Sockets.		A	B	C
			Pipe, in.	Special Castings, in.	Pipe, in.	Special Castings, in.			
54	C	57.80	58.80	58.80	5.50	5.50	2.25	4.00	2.15
54	D	58.40	59.40	59.40	5.50	5.50	2.25	4.40	2.45
60	A	62.80	63.80	63.80	5.50	5.50	2.25	3.40	1.70
60	B	63.40	64.40	64.40	5.50	5.50	2.25	3.70	1.90
60	C	64.20	65.20	65.20	5.50	5.50	2.25	4.20	2.25
60	D	64.82	65.82	65.82	5.50	5.50	2.25	4.70	2.60

having spigot ends shall have outside diameters of spigot ends midway between the two standards of outside diameter as shown by Table I, and shall be tapered back for a distance of 6 in. For pipes from 14 in. to 24 in., inclusive, two classes of special castings shall be furnished, Class B special castings with Classes A and B pipes, and Class D special castings with Classes C and D pipes, the former to be stamped "AB" and the latter to be stamped "CD." For pipes 30 in. to 60 in., inclusive, four classes of special castings shall be furnished, one for each class of pipe, and shall be stamped with the letter of the class to which they belong.

ALLOWABLE VARIATION IN DIAMETER OF PIPES AND SOCKETS.

SECTION 2. Especial care shall be taken to have the sockets of the required size. The sockets and spigots will be tested by circular gages, and no pipe will be received which is defective in joint room from any cause. The diameters of the sockets and the outside diameters of the bead ends of the pipes shall not vary from the standard dimensions by more than 0.06 in. for pipes 16 in. or less in diameter; 0.08 in. for 18-in., 20-in. and 24-in. pipes; 0.10 in. for 30-in., 36-in. and 42-in. pipes; 0.12 in. for 48-in. pipes; and 0.15 in. for 54-in. and 60-in. pipes.

ALLOWABLE VARIATION IN THICKNESS.

SECTION 3. For pipes whose standard thickness is less than 1 in., the thickness of metal in the body of the pipe shall not be more than 0.08 in. less than the standard thickness; and for pipes whose standard thickness is 1 in. or more, the variation shall not exceed 0.10 in., except that for spaces not exceeding 8 in. in length in any direction, variations from the standard thickness of 0.02 in. in excess of the allowance above given shall be permitted.

TABLE II.—STANDARD THICKNESSES AND WEIGHTS OF CAST-IRON PIPE.

Nominal Inside Diameter, in.	CLASS A. 100 FT. HEAD. 43 LB. PRESSURE.			CLASS B. 200 FT. HEAD. 86 LB. PRESSURE.			CLASS C. 300 FT. HEAD. 130 LB. PRESSURE.			CLASS D. 400 FT. HEAD. 173 LB. PRESSURE.			Nominal Inside Diameter, in.
	Thickness, in.	Weight per		Thickness, in.	Weight per		Thickness, in.	Weight per		Thickness, in.	Weight per		
		Foot.	Length.		Foot.	Length.		Foot.	Length.		Foot.	Length.	
4	0.42	20.0	240	0.45	21.7	260	0.48	23.3	280	0.52	25.0	300	4
6	0.44	30.8	370	0.48	33.3	400	0.51	35.8	430	0.55	38.3	460	6
8	0.46	42.9	515	0.51	47.5	570	0.56	52.1	625	0.60	55.8	670	8
10	0.50	57.1	685	0.57	63.8	765	0.62	70.8	850	0.68	76.7	920	10
12	0.54	72.5	870	0.62	82.1	985	0.68	91.7	1 100	0.75	100.0	1 200	12
14	0.57	89.6	1 075	0.66	102.5	1 230	0.74	116.7	1 400	0.82	129.2	1 550	14
16	0.60	108.3	1 300	0.70	125.0	1 500	0.80	143.8	1 725	0.89	158.3	1 900	16
18	0.64	129.2	1 550	0.75	150.0	1 800	0.87	175.0	2 100	0.96	191.7	2 300	18
20	0.67	150.0	1 800	0.80	175.0	2 100	0.92	208.3	2 500	1.03	229.2	2 750	20
24	0.76	204.2	2 450	0.89	233.3	2 800	1.04	279.2	3 350	1.16	306.7	3 680	24
30	0.88	291.7	3 500	1.03	333.3	4 000	1.20	400.0	4 800	1.37	450.0	5 400	30
36	0.99	391.7	4 700	1.15	454.2	5 450	1.36	545.8	6 550	1.58	625.0	7 500	36
42	1.10	512.5	6 150	1.28	591.7	7 100	1.54	716.7	8 600	1.78	825.0	9 900	42
48	1.26	666.7	8 000	1.42	750.0	9 000	1.71	908.3	10 900	1.96	1 050.0	12 600	48
54	1.35	800.0	9 600	1.55	933.3	11 200	1.90	1 141.7	13 700	2.23	1 341.7	16 100	54
60	1.39	916.7	11 000	1.67	1 104.2	13 250	2.00	1 341.7	16 100	2.38	1 583.3	19 000	60

The above weights are for 12 ft. laying lengths and standard sockets; proportionate allowance to be made for any variation therefrom.

For special castings of standard patterns a variation of 50 per cent greater than allowed for straight pipe shall be permitted.

DEFECTIVE SPIGOTS MAY BE CUT.

SECTION 4. Defective spigot ends on pipes 12 in. or more in diameter may be cut off in a lathe, and a half-round wrought-iron band shrunk into a groove cut in the end of the pipe. Not more than 12 per cent of the total number of accepted pipes of each size shall be cut and banded, and no pipe shall be banded which is less than 11 ft. in length, exclusive of the socket.

In case the length of a pipe differs from 12 ft., the standard weight of the pipe given in Table II shall be modified in accordance therewith.

SPECIAL CASTINGS.

SECTION 5. All special castings shall be made in accordance with the cuts and the dimensions given in the table forming a part of these specifications.

The diameters of the sockets and the external diameters of the bead ends of the special castings shall not vary from the standard dimensions by more than 0.12 in. for castings 16 in. or less in diameter; 0.15 in. for 18-in., 20-in. and 24-in. pipes; 0.20 in. for 30-in., 36-in. and 42-in. pipes; and 0.24 in. for 48-in., 54-in. and 60-in. pipes. These variations apply only to special castings made from standard patterns.

The flanges on all manhole castings and manhole covers shall be faced true and smooth, and drilled to receive bolts of the sizes given in the tables. The manufacturer shall furnish and deliver all bolts for bolting on the manhole covers, the bolts to be of the sizes shown on plans and made of the best quality of mild steel, with hexagonal heads and nuts and sound, well-fitting threads.

MARKING.

SECTION 6. Every pipe and special casting shall have distinctly cast upon it the initials of the maker's name. When cast especially to order, each pipe and special casting larger than 4 in. may also have cast upon it figures showing the year in which it was cast and a number signifying the order in point of time in which it was cast, the figures denoting the year being above and the number below, thus:

1901	1901	1901
1	2	3

etc., also any initials, not exceeding four, which may be required by the purchaser. The letters and figures shall be cast on the outside and shall be not less than 2 in. in length and $\frac{1}{8}$ in. in relief for pipes 8 in. in diameter and larger. For smaller sizes of pipes the letters may be 1 in. in length. The weight and the class letter shall be conspicuously painted in white on the inside of each pipe and special casting after the coating has become hard.

ALLOWABLE PERCENTAGE OF VARIATION IN WEIGHT.

SECTION 7. No pipe shall be accepted the weight of which shall be less than the standard weight by more than 5 per cent for pipes 16 in. or less in diameter, and 4 per cent for pipes more than 16 in. in diameter; and no excess above the standard weight of more than the given percentages for the several sizes shall be paid for. The total weight to be paid for shall not exceed for each size and class of pipe received the sum of the standard weights of the same number of pieces of the given size and class by more than 2 per cent.

No special casting shall be accepted the weight of which shall be less than the standard weight by more than 10 per cent for pipes 12 in. or less in diameter, and 8 per cent for larger sizes, except that curves, Y-pieces and breeches pipe may be 12 per cent below the standard weight, and no excess above the standard weight of more than the above percentages for the several sizes will be paid for. These variations apply only to castings made from the standard patterns.

QUALITY OF IRON.

SECTION 8. All pipes and special castings shall be made of cast iron of good quality, and of such character as shall make the metal of the castings strong, tough and of even grain, and soft enough to satisfactorily admit of drilling and cutting. The metal shall be made without any admixture of cinder iron or other inferior metal, and shall be remelted in a cupola or air furnace.

TESTS OF MATERIALS.

SECTION 9. Specimen bars of the metal used, each being 26 in. long by 2 in. wide and 1 in. thick, shall be made without charge as often as the engineer may direct, and, in default of definite instructions, the contractor shall make and test at least one bar from each heat or run of metal. The bars, when placed

flat-wise upon supports 24 in. apart and loaded in the center, shall, for pipes 12 in. or less in diameter, support a load of 1900 lb. and show a deflection of not less than 0.30 in. before breaking; and for pipes of sizes larger than 12 in., they shall support a load of 2000 lb. and show a deflection of not less than 0.32 in. The contractor shall have the right to make and break three bars from each heat or run of metal, and the test shall be based upon the average results of the three bars. Should the dimensions of the bars differ from those above given, a proper allowance therefor shall be made in the results of the tests.

CASTING OF PIPES.

SECTION 10. The straight pipes shall be cast in dry sand molds in a vertical position. Pipes 16 in. or less in diameter shall be cast with the hub end up or down, as specified in the proposal. Pipes 18 in. or more in diameter shall be cast with the hub end down.

The pipes shall not be stripped or taken from the pit while showing color of heat, but shall be left in the flasks for a sufficient length of time to prevent unequal contraction by subsequent exposure.

QUALITY OF CASTINGS.

SECTION 11. The pipes and special castings shall be smooth, free from scales, lumps, blisters, sand holes and defects of every nature which unfit them for the use for which they are intended. No plugging or filling will be allowed.

CLEANING AND INSPECTION.

SECTION 12. All pipes and special castings shall be thoroughly cleaned and subjected to a careful hammer inspection. No casting shall be coated unless entirely clean and free from rust, and approved in these respects by the engineer immediately before being dipped.

COATING.

SECTION 13. Every pipe and special casting shall be coated inside and out with coal-tar pitch varnish. The varnish shall be made from coal tar. To this material sufficient oil shall be added to make a smooth coating, tough and tenacious when cold, and not brittle nor with any tendency to scale off.

Each casting shall be heated to a temperature of 300° F. immediately before it is dipped, and shall possess not less than

this temperature at the time it is put in the vat. The ovens in which the pipes are heated shall be so arranged that all portions of the pipe shall be heated to an even temperature. Each casting shall remain in the bath at least five minutes.

The varnish shall be heated to a temperature of 300° F. (or less if the engineer shall so order), and shall be maintained at this temperature during the time the casting is immersed.

Fresh pitch and oil shall be added when necessary to keep the mixture at the proper consistency, and the vat shall be emptied of its contents and refilled with fresh pitch when deemed necessary by the engineer. After being coated, the pipes shall be carefully drained of the surplus varnish. Any pipe or special casting that is to be re-coated shall first be thoroughly scraped and cleaned.

HYDROSTATIC TEST.

SECTION 14. When the coating has become hard, the straight pipes shall be subjected to a proof by hydrostatic pressure and, if required by the engineer, they shall also be subjected to a hammer test under this pressure.

The pressure to which the different sizes and classes of pipes shall be subjected are as follows:

	20-In. Diameter and Larger, lb. per sq. in.	Less than 20-In. Diameter, lb. per sq. in.
Class A pipe	150	300
Class B pipe	200	300
Class C pipe	250	300
Class D pipe	300	300

WEIGHING.

SECTION 15. The pipes and special castings shall be weighed for payment under the supervision of the engineer after the application of the coal-tar pitch varnish. If desired by the engineer the pipes and special castings shall be weighed after their delivery, and the weights so ascertained shall be used in the final settlement, provided such weighing is done by a legalized weighmaster. Bids shall be submitted and a final settlement made on the basis of a ton of 2000 lb.

CONTRACTOR TO FURNISH MEN AND MATERIALS.

SECTION 16. The contractor shall provide all tools, testing machines, materials and men necessary for the required

testing, inspection and weighing at the foundry of the pipes and special castings; and, should the purchaser have no inspector at the works, the contractor shall, if required by the engineer, furnish a sworn statement that all of the tests have been made as specified, this statement to contain the results of the tests upon the test bars.

POWER OF ENGINEER TO INSPECT.

SECTION 17. The engineer shall be at liberty at all times to inspect the material at the foundry, and the molding, casting and coating of the pipes and special castings. The forms, sizes, uniformity and conditions of all pipes and other castings herein referred to shall be subject to his inspection and approval, and he may reject, without proving, any pipes or other castings which are not in conformity with the specifications or drawings.

INSPECTOR TO REPORT.

SECTION 18. The inspector at the foundry shall report daily to the foundry office all pipes and special castings rejected, with the causes for rejection.

CASTINGS TO BE DELIVERED SOUND AND PERFECT.

SECTION 19. All the pipes and other castings must be delivered in all respects sound and conformable to these specifications. The inspection shall not relieve the contractor of any of his obligations in this respect, and any defective pipe or other castings which may have passed the engineer at the works or elsewhere shall be at all times liable to rejection when discovered until the final completion and adjustment of the contract, provided, however, that the contractor shall not be held liable for pipes or special castings found to be cracked after they have been accepted at the agreed point of delivery. Care shall be taken in handling the pipes not to injure the coating, and no pipes or other material of any kind shall be placed in the pipes during transportation or at any time after they receive the coating.

DEFINITION OF THE WORD "ENGINEER."

SECTION 20. Wherever the word "engineer" is used herein, it shall be understood to refer to the engineer or inspector acting for the purchaser and to his properly authorized agents, limited by the particular duties intrusted to them.

STANDARD SPECIFICATIONS

FOR

CAST-IRON SOIL PIPE AND FITTINGS[1]

Serial Designation: A 74 – 18

These specifications are issued under the fixed designation A 74; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1917; ADOPTED, 1918.

MANUFACTURE

Cast Iron.

1. The cast iron from which the pipe and fittings are made shall be of such composition, and the conditions of manufacture so maintained, that the castings will be of uniform physical character, close-grain, and not hard, brittle nor difficult to cut with file or chisel.

Coating for Cast Iron.

2. (*a*) When pipe or fittings are to be coated, coal-tar pitch shall be used, which shall contain sufficient oil to make a smooth coating. The pitch shall be tough and tenacious when cold, and not brittle nor having any tendency to scale.

(*b*) The varnish shall be heated to about 300° F. and shall remain at this temperature during the time the casting is immersed.

(*c*) Each casting shall be heated to a uniform temperature of about 300° F. immediately before it is dipped, and shall possess this temperature at the time it is put in the bath.

(*d*) Each casting shall remain in the bath at least two minutes.

(*e*) Fresh pitch and oil shall be added when necessary to keep the mixture of the proper consistency, and the vat shall be emptied of its contents and refilled with fresh pitch whenever the accumulation of sand or carbonaceous matter renders this desirable, as can be seen by the solids adhering to the under side or lower ends of the castings.

(*f*) After being coated, the pipe and fittings shall be carefully drained of the surplus varnish.

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-3 on Cast Iron.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

3. Drillings taken from the fractured end of the arbitration test bar shall not contain over 0.10 per cent of sulfur.

PHYSICAL PROPERTIES AND TESTS

Transverse Tests.

4. The transverse test specimens (arbitration test bars) specified in Section 7, when placed horizontally upon supports

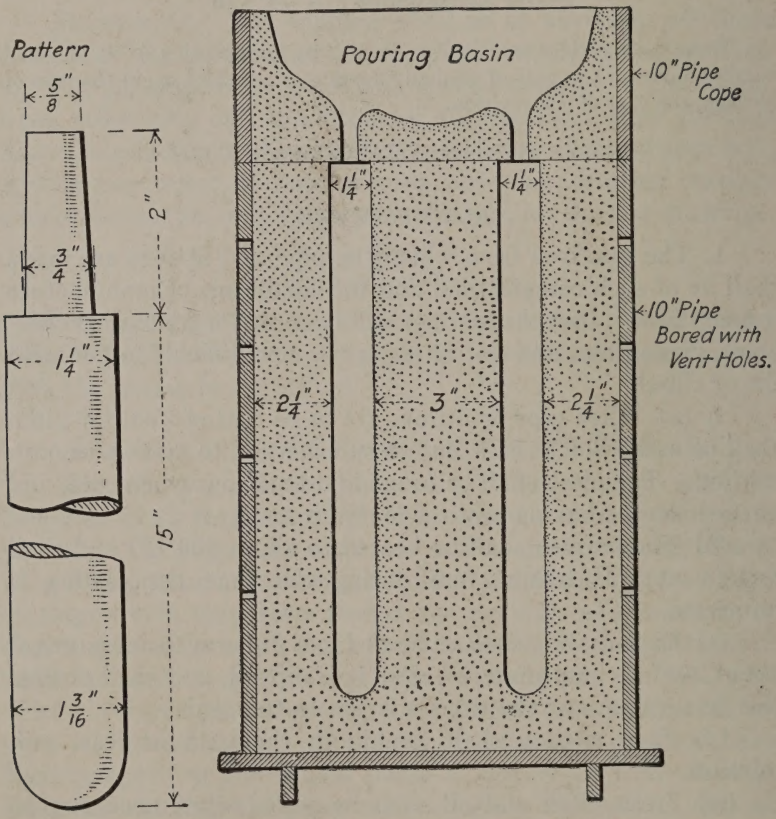


FIG. 1.—Mold for Arbitration Test Bar

12 in. apart and tested under a centrally applied load, shall conform to the following minimum requirements:

Average load at center, lb	2500
Average deflection at center, in	0.10

Hydrostatic Tests.

5. All pipe shall be tested to a hydrostatic pressure of not less than 50 lb. per sq. in. before coating. Any casting showing

defects under this hydrostatic test shall be promptly broken and returned to the cupola.

Mold for Test Specimens.

6. The form and dimensions of the mold for the arbitration test bar shall be in accordance with Fig. 1. The bottom of the bar shall be $\frac{1}{16}$ in. smaller in diameter than the top, to allow for draft and for the strain of pouring. The pattern shall not be rapped before withdrawing. The flask shall be rammed up with green molding sand, a little damper than usual, well mixed and put through a No. 8 sieve, with a mixture of 1 to 12 bituminous facing. The mold shall be rammed evenly and fairly hard, thoroughly dried, and not cast until it is cold. The test bar shall not be removed from the mold until cold enough to be handled. It shall not be rumbled or otherwise treated, being simply brushed off before testing.

TABLE I.—WEIGHTS OF SOIL PIPE.

Size, in.	Single Hub.		Double Hub.
	Per 5-ft. Length, lb.	Per ft. including Hub, lb.	Per 5-ft. Length lb.
2	27½	5½	27½
3	47½	9½	47½
4	65	13	65
5	85	17	85
6	100	20	100

Number of Specimens.

7. From each melt of metal not less than three test specimens (arbitration test bars) shall be poured, the first of which shall be poured within five minutes after the first ladle is tapped and the remainder at intervals not exceeding one hour throughout the melt.

STANDARD SIZES AND WEIGHTS

Sizes.

8. (*a*) The inside diameter of the barrel of any pipe or fittings or branch thereof shall not vary more than $\frac{1}{8}$ in. under the nominal size of pipe.

(*b*) The outside diameter of the barrel of pipe and fittings shall be $\frac{1}{2}$ in. greater than its nominal inside diameter A variation in the outside diameter of $\frac{1}{8}$ in. over or under these figures will be permitted.

(*c*) All pipe and fittings shall be of uniform thickness of wall and present true circles at the hub and spigot ends. A variation of $\frac{1}{16}$ in. under the following dimensions will be permitted, but

only when the actual weight is not less than the variation of the marked or estimated weight as given in Tables I and II:

Thickness of barrel	$\frac{1}{4}$ in.
" " body of hub	$\frac{5}{16}$ "
" " bead of hub	$\frac{1}{2}$ "
" " bead of spigot end	$\frac{7}{16}$ "

TABLE II.—WEIGHTS OF SOIL PIPE FITTINGS.

ONLY THE STAPLE FITTINGS ARE SHOWN. FROM THE DATA HEREWITH THE WEIGHTS OF OTHER FITTINGS MAY BE CALCULATED.

All values are in pounds.

Fittings.	Size of Fittings, in.														
	2	3	4	5	6	3 by 2	4 by 2	4 by 3	5 by 2	5 by 3	5 by 4	6 by 2	6 by 3	6 by 4	6 by 5
$\frac{1}{4}$ Bends, regular	$6\frac{3}{4}$	$10\frac{1}{4}$	15	19	$23\frac{1}{2}$	....	....	....	....	....	....	....	....	....	....
$\frac{1}{4}$ Bends, short sweep	$8\frac{1}{4}$	$12\frac{1}{2}$	$17\frac{3}{4}$	$22\frac{1}{2}$	$27\frac{1}{2}$	....	....	....	....	....	....	....	....	....	....
$\frac{1}{4}$ Bends, long sweep	$10\frac{1}{4}$	$15\frac{3}{4}$	22	$27\frac{1}{2}$	$33\frac{1}{2}$	....	....	....	....	....	....	....	....	....	....
$\frac{1}{5}$ Bends	$6\frac{1}{4}$	$9\frac{3}{4}$	$13\frac{3}{4}$	$17\frac{1}{2}$	$21\frac{1}{2}$	....	....	....	....	....	....	....	....	....	....
$\frac{1}{6}$ Bends	6	$9\frac{1}{4}$	13	$16\frac{1}{2}$	20	....	....	....	....	....	....	....	....	....	....
$\frac{1}{8}$ Bends	$5\frac{1}{2}$	$8\frac{1}{2}$	$12\frac{1}{4}$	$15\frac{1}{4}$	$18\frac{1}{4}$	....	....	....	....	....	....	....	....	....	....
$\frac{1}{16}$ Bends	5	$7\frac{3}{4}$	$10\frac{3}{4}$	$13\frac{1}{4}$	$15\frac{3}{4}$	....	....	....	....	....	....	....	....	....	....
Return Bends	$8\frac{3}{4}$	14	$20\frac{1}{4}$	$26\frac{1}{2}$	$33\frac{1}{2}$	....	....	....	....	....	....	....	....	....	....
Tees	$10\frac{1}{4}$	$15\frac{1}{4}$	21	$26\frac{1}{2}$	$32\frac{1}{2}$	$13\frac{1}{4}$	$16\frac{1}{2}$	$18\frac{3}{4}$	$19\frac{1}{4}$	22	$24\frac{1}{2}$	$22\frac{1}{2}$	25	$27\frac{1}{2}$	30
Tapped Tees (tapped up to 2 in.)	$8\frac{3}{4}$	....	....	....	....	$11\frac{3}{4}$	15	....	$17\frac{3}{4}$	....	....	$20\frac{1}{2}$	....	....	....
Sanitary Tees	11	$16\frac{1}{4}$	$22\frac{1}{2}$	28	$34\frac{1}{2}$	14	$17\frac{1}{4}$	$19\frac{3}{4}$	20	23	$25\frac{1}{2}$	23	26	29	$31\frac{1}{2}$
Tapped Sanitary Tees (tapped up to 2 in.)	9	....	....	....	....	12	$15\frac{1}{4}$	....	18	....	....	$21\frac{1}{4}$	....	....	....
Y Branch	11	17	24	$31\frac{1}{2}$	$39\frac{1}{2}$	14	$17\frac{1}{4}$	$20\frac{1}{2}$	20	$23\frac{1}{2}$	$27\frac{1}{2}$	23	27	31	35
$\frac{1}{2}$ Y Branch	$10\frac{1}{4}$	$15\frac{1}{2}$	$21\frac{1}{2}$	$27\frac{1}{2}$	34	$13\frac{1}{2}$	$16\frac{1}{2}$	19	$19\frac{1}{2}$	22	25	$22\frac{1}{2}$	$25\frac{1}{2}$	$28\frac{1}{2}$	31
Tapped Inverted Y Branch (tapped up to 2 in.)	$10\frac{1}{4}$	$13\frac{3}{4}$	$17\frac{1}{2}$	21	24	....	....	....	....	....	....	....	....	....	....
Inverted Y Branch	$11\frac{1}{2}$	18	$25\frac{1}{2}$	33	$41\frac{1}{2}$	15	$18\frac{3}{4}$	22	22	$25\frac{1}{2}$	$29\frac{1}{2}$	$25\frac{1}{2}$	$29\frac{1}{2}$	33	37
Combination Y and $\frac{1}{8}$ Bend	12	$18\frac{3}{4}$	27	35	$44\frac{1}{2}$	15	$18\frac{1}{4}$	$22\frac{1}{2}$	21	$25\frac{1}{2}$	$30\frac{1}{2}$	24	29	34	39
Upright Y Branch	$12\frac{1}{2}$	$19\frac{1}{2}$	28	$36\frac{1}{2}$	46	$15\frac{3}{4}$	$18\frac{3}{4}$	23	$21\frac{1}{2}$	$26\frac{1}{2}$	$31\frac{1}{2}$	$24\frac{1}{2}$	$29\frac{1}{2}$	35	40

Weights. 9. (*a*) Weights and measurements of pipe and fittings shall be taken as those of plain uncoated pipe. All weights shall be given in pounds.

(*b*) Individual lengths of pipe and fittings may weigh 5 per cent less than designated in Tables I and II, but only when the average weight of a given size and weight of pipe and fittings selected at random, is not less than that shown in Tables I and II.

(*c*) The regular length of pipe shall be such as to lay 5 ft. including hub.

(*d*) The average weights of soil pipe and fittings shall not be less than those given in Tables I and II.

WORKMANSHIP AND FINISH

Character of Castings.

10. (*a*) All pipe and fittings shall be practically straight and cylindrical and fittings true to pattern. The specified sizes shall be for the inside diameter and shall conform, within the allowable variation, to the dimensions given in the tables.

(*b*) All pipe and fittings shall be carefully examined for defects and sounded with a hammer before shipment. No fillings with metal, cement or other material, or so-called "burning on" of iron will be permitted. The castings shall be sound and free from cracks, sand-holes, blow-holes and cold-shots.

MARKING

Marking.

11. All pipe and fittings shall be marked with the name of the manufacturer, or appropriate initial. Each casting shall have cast upon it the minimum or estimated weight of same as shown in Tables I and II.

INSPECTION AND REJECTION

Inspection.

12. The manufacturer shall afford the inspector representing the purchaser, free of cost, all reasonable facilities to satisfy him that the castings are being furnished in accordance with these specifications. All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works, and shall be made prior to shipment, unless otherwise specified.

Rejection.

13. All pipe and fittings which fail to conform to the provisions of these specifications shall be subject to rejection.

STANDARD SPECIFICATIONS
FOR
CAST-IRON LOCOMOTIVE CYLINDERS[1]

Serial Designation: A 45 – 14

These specifications are issued under the fixed designation A 45; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ADOPTED, 1904; REVISED, 1911, 1914.

MANUFACTURE

Process. 1. Locomotive cylinders shall be made from good quality, close-grain gray iron cast in a dry mold.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition. 2. Drillings taken from the fractured end of the transverse test bars shall conform to the following requirements as to chemical composition:

Phosphorus	not over 0.90 per cent
Sulfur	" " 0.12 "

Check Analyses. 3. A check analysis of drillings taken from the transverse test bar may be made by the purchaser. The phosporous and sulfur content thus determined shall conform to the requirements specified in Section 2.

PHYSICAL PROPERTIES AND TESTS

Transverse Tests. 4. The transverse test specimens (arbitration test bars) specified in Section 6 (*a*), when placed horizontally upon supports 12 in. apart and tested under a centrally applied load, shall conform to the following minimum requirements:

Average load at center, lb	3 200
Average deflection at center, in	0.09

Chill Tests. 5. Before pouring, a sample of the iron shall be taken and chilled in a cast-iron mold, as specified in Section 6 (*b*). The sample shall be allowed to cool in the mold until it is dark red or almost black, when it shall be knocked out and quenched in water. This chill test specimen, on being broken, shall show

[1]Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-3 on Cast Iron.

a close-grain gray iron, with a well-defined border of white iron at the bottom of the fracture. The depth of the white iron shall not be less than $\frac{1}{16}$ in. as measured at the center line.

Molds for Test Specimens.

6. (*a*) *Arbitration Test Bar.*—The form and dimensions of the mold for the arbitration test bar shall be in accordance with Fig. 1. The bottom of the bar shall be $\frac{1}{16}$ in. smaller in diameter than the top, to allow for draft and for the strain of pouring.

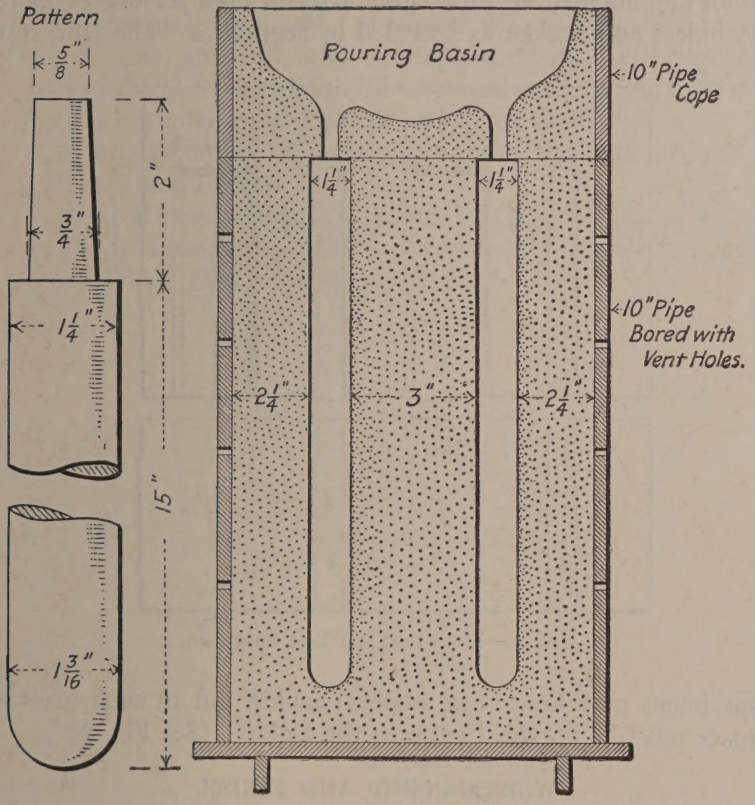


FIG. 1.—Mold for Arbitration Test Bar.

The pattern shall not be rapped before withdrawing. The flask shall be rammed up with green molding sand, a little damper than usual, well mixed and put through a No. 8 sieve, with a mixture of 1 to 12 bituminous facing. The mold shall be rammed evenly and fairly hard, thoroughly dried, and not cast until it is cold. The test bar shall not be removed from the mold until cold enough to be handled. It shall not be rumbled or otherwise treated, being simply brushed off before testing.

(*b*) *Chill Test Specimen.*—The form and dimensions of the mold for the chill test specimen shall be in accordance with Fig. 2.

Number of Tests. 7. (*a*) Two arbitration test bars, cast as specified in Section 6 (*a*), shall be poured from each ladle of metal used for one or more cylinders, and tested as specified in Section 4.

(*b*) One chill test specimen, cast as specified in Section 6 (*b*), shall be poured from each ladle of metal used for one or more cylinders and broken as specified in Section 5. The chill test

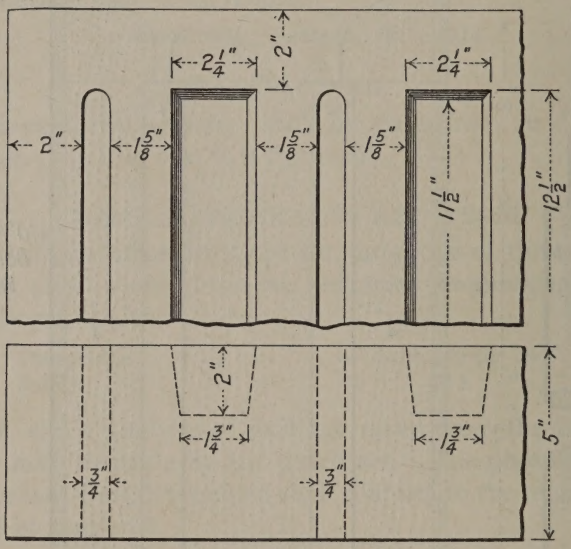


FIG. 2.—Mold for Chill Test Specimen.

specimens may be cast in adjacent molds, but in such cases a space must be provided between the molds. (See Fig. 2.)

WORKMANSHIP AND FINISH

Character of Castings. 8. The cylinders shall be smooth, well-cleaned, free from shrinkage cracks and from other defects sufficiently extensive to impair the value of the castings, and shall finish to the size specified by the purchaser.

MARKING

Marking. 9. Marks designating the maker, the date of casting, the serial and pattern numbers and other marks specified by the purchaser, shall be cast on each cylinder in raised letters.

INSPECTION AND REJECTION

10. (*a*) The inspector representing the purchaser shall be given a reasonable opportunity to enable him to witness the pouring of the cylinders and test specimens, as well as to be present when physical tests are made. **Inspection.**

(*b*) In case the inspector is not present to witness the pouring of the cylinders and test specimens, the manufacturer will make all tests required by these specifications. He will, upon demand, furnish the purchaser with a copy of the results of his tests, and will hold the transverse and chill test specimens subject to examination by the inspector. The tests made by the manufacturer shall be considered final.

(*c*) All physical tests and inspection shall be made at the place of manufacture.

11. Unless otherwise specified, any rejection based on tests made in accordance with Section 3 shall be reported within five working days from the receipt of samples. **Rejection.**

STANDARD SPECIFICATIONS
FOR
CHILLED CAST-IRON WHEELS[1]

Serial Designation: A 46 – 24

These specifications are issued under the fixed designation A 46; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ADOPTED, 1905; REVISED, 1924.

MATERIAL

Material.

1. Wheels shall be made of a mixture of such composition that will produce the required chill in the tread and not show any mottled iron in the plates except around the chaplets where it shall not extend more than $\frac{1}{2}$ in. (12.7 mm.). (The use of steel chaplets is preferred.)

CHEMICAL REQUIREMENTS

Chemical Composition.

2. (*a*) The wheels shall conform to the following requirements as to chemical composition:

	MINIMUM.	MAXIMUM.
Total carbon, per cent.....	3.25	....
Combined carbon, per cent..	....	0.85
Silicon, per cent.....	0.45	0.75
Manganese, per cent.....	0.50	0.75
Phosphorus, per cent.....	....	0.40
Sulfur, per cent.....	....	0.17 for 1923 to 1924, incl. 0.16 " 1925 " 1926, " 0.15 " 1927 " 1928, " 0.14 ,, 1929 and thereafter

Analyses.

(*b*) The minimum percentage of manganese shall be not less than three times the sulfur content.

3. Analysis shall be made by the manufacturer from test blocks poured during the day's melt from each cupola from which wheels purchased under these specifications are poured to determine the percentages of total carbon, manganese, phosphorus, sulfur and silicon. The chemical composition thus determined shall be reported to the purchaser or his representative upon request.

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-3 on Cast Iron.

Check Analyses.

4. Drillings for check chemical analysis shall be taken from drill hole bored entirely through the back double plate of the wheel midway between the core leg holes.

DIMENSIONS, WEIGHT AND DESIGN OF WHEELS

Patterns.

5. Patterns and chillers shall be such that they will produce wheels according to the dimensions shown on drawings furnished by the purchaser.

Dimensions.

6. The normal circumference conforming to the specified diameter shall be measured at a point $1\frac{23}{32}$ in. (43.65 mm.) from the gaging point on the throat of the flange. Wheels shall not vary more than $\frac{7}{16}$ in. (11.11 mm.) above or below normal size, measured on the circumference, but only $\frac{5}{16}$ in. (7.94 mm.) variation above or below normal size shall be allowed for any day's cast from one cupola.

The thickness of the flange shall be regulated by a maximum and minimum flange thickness gage which shall be not more than $\frac{1}{16}$ in. (1.59 mm.) over nor more than $\frac{1}{16}$ in. (1.59 mm.) under the normal flange.

Taping.

7. All wheels shall be taped with a standard design of wheel circumference tape and have the numbers 1, 2, 3, 4, and 5 stamped $\frac{1}{8}$ in. (3.18 mm.) apart, the figure "3" to represent normal tape size limited by $\frac{1}{16}$ in. (1.59 mm.) over or under the standard circumference, which for 33 in. (838.2 mm.) wheels will be 103.67 in. (2633.2 mm.). The figure "1" shall represent the smallest diameter, and the figure "5" the largest diameter. Tape sizes shall be stenciled in plain figures on the plate of the wheel or otherwise designated, as may be required by the purchaser.

Weights.

8. (*a*) If wheels are ordered in accordance with A.R.A. standard drawings the weights shall be as follows:

Maximum Gross Weight of Car.		Normal Weight of Wheel.		Minimum Weight of Wheel.	
Lb.	Kg.	Lb.	Kg.	Lb.	Kg.
95 000	43 000	650	295	640	290
132 000	59 750	700	317	690	313
169 000	76 500	750	340	740	335
210 000	95 250	850	385	835	380

(*b*) In the case of wheels ordered with cores smaller in diameter than the standard, the additional weight shall be considered as additional to the normal weight given in the above table and be paid for by the purchaser.

(*c*) In any shipment where the average weight of wheels is above the normal weight given in the above table the excess weight shall be at the expense of the manufacturer.

INSPECTION

Inspection. 9. The inspector representing the purchaser shall have free entry at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the wheels ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the wheels are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Surface. 10. The body of the wheel shall be free from slag, shrinkage, or blow holes. The tread and throat shall be free from irregular wrinkles, slag, sand wash, chill cracks or sweat. Wheels will not be rejected on account of cracks around the circumference of the center core commonly known as "drawn hubs" or slight shrinkage holes on the face of the hub which will not interfere with the proper mounting of the wheels.

Marking. 11. All wheels shall be marked and numbered consecutively in accordance with instructions issued by the purchaser. All wheels shall have the initials of the purchaser, wheel number, weight of wheel, month, day and year when made plainly cast on the inside plate of the wheel. No wheels shall have duplicate numbers and all indistinct or duplicate numbers may be corrected only after having received the approval of the inspector. All wheels shall have the name of the manufacturer and place of manufacture cast on the outside plate of the wheel.

Sampling. 12. When ready for inspection, the wheels shall be arranged in groups, all wheels of the same date being grouped together, and for each 102 wheels which pass inspection and are ready for shipment, two representative wheels shall be taken, one of which shall be subjected to the thermal test and the other shall be used for the drop test.

Thermal Test. 13. (*a*) In making the thermal test the wheels shall be laid with the flange downward in the sand and a channel-way $1\frac{3}{4}$-in. (44 mm.) in width at the center of the tread for all wheels up to and including 700 lb. in weight and 2 in. (51 mm.) in width at the center of the tread for all wheels over 700 lb. in weight and 4 in. (102 mm.) deep shall be molded in green sand around the wheel, the tread of the wheel to form one side of the channel-way and the clean flange forming as much of the bottom as its width will cover. This channel-way shall be filled with molten cast iron which shall be hot enough when poured, so that the ring cast, when the metal is cold, will be solid and free from wrinkles. The time when pouring ceases shall be noted and after two minutes

has elapsed an examination of the wheel shall be made. If any cracks develop in any part of the wheel, all wheels bearing the same tape size as represented by the sample shall be rejected.

(*b*) In order to prevent spitting while pouring, the tread and flange may be covered with a coat of shellac. Wheels selected for test which are wet or which have been exposed to snow or frost may be warmed sufficiently to dry them or remove the frost before testing, but under no circumstances shall the thermal test be applied to a wheel that in any part feels warm to the hand.

Drop Test.

14. (*a*) The anvil of the drop testing machine shall be supported on rubble masonry or a concrete foundation at least 2 ft. (610 mm.) deep and shall weigh not less than 1700 lb. (770 kg.). The striking face of the tup shall be 9 in. (229 mm.) in diameter and flat. The face of each of the three bosses supporting the wheel under test shall be flat and measure 5 in. (127 mm.) in width.

(*b*) The test wheel shall be so placed on the three supports with the flange down, that the tup will strike centrally on the hub. The test wheel shall pass the requirements given in Table I without breaking in two or more pieces. If the test wheel fails, all wheels bearing the same tape size shall be rejected.

TABLE I.

Weight of Wheel.		Weight of Tup.		Height of Drop.		Number of Blows.
Lb.	Kg.	Lb.	Kg.	Ft.	M.	
650	295	250	113	9	2.75	12
700	317	250	113	10½	3.20	12
750	340	250	113	12	3.65	12
850	385	250	113	15	4.60	12

(*c*) If the test wheel cracks before the twelfth blow it shall be required to stand 15 blows before breaking in two or more pieces.

Chill Test.

15. The wheel selected for the drop and thermal test shall, following such test, be broken so that the chill may be examined at least four different portions of the wheel. The depth of pure white iron shall conform to the following requirements:

Weight of Wheel.		Maximum Depth.				Minimum Depth.			
		At Middle of Tread.		At Throat.		At Middle of Tread.		At Throat.	
Lb.	Kg.	In.	mm.	In.	mm.	In.	mm.	In.	mm.
650	295	1	25.5	⅞	22.2	½	12.7	⅜	9.5
700	317	1 1/16	27.	⅞	22.2	½	12.7	7/16	11.1
750	340	1⅛	28.6	⅞	22.2	½	12.7	½	12.7
850	385	1⅛	28.6	⅞	22.2	½	12.7	½	12.7

The depth of the chill shall not vary more than ¼ in. (6.35 mm.) in the middle of the tread on the different portions measured. If the

sample does not conform to the requirements stated, all wheels of the tape size represented by the sample shall be rejected.

NOTE: The chill and physical tests specified only cover 33-in. wheels of the weights listed. Requirements for wheels of other sizes are to be supplied by the committee.

RETEST

Retest.

16. Should the test wheel selected for the drop test, thermal test, or chill test fail to meet the requirements specified, all wheels bearing the same tape size shall be rejected (Sections 13, 14 and 15). The inspector shall then select another wheel of a different tape size, which shall be submitted to the same test as the wheel which failed and if it passes the requirements of the test the remainder of the lot shall be accepted, provided the requirements of all other tests have been met.

REJECTION

Rejection.

17. The numbers of all wheels which have been rejected because of failure to meet the requirements of the drop test, thermal test, or chill test shall be noted and such wheels shall not be submitted for test at any future time.

Individual Rejection.

18. Individual wheels shall be rejected if:

(*a*) They are under the minimum weight specified;

(*b*) They have surface defects mentioned in Section 10;

(*c*) They are over or under the specified dimensions.

As information of possible value to the users of these specifications, Committee A-3 on Cast Iron wishes to state that the Association of Manufacturers of Chilled Car Wheels have adopted recommended designs of cast-iron car wheels of 24, 26, 28, 30, 33, 36, 39 and 42-in. diameter. The designs for the 33-in. diameter wheels have been approved by the American Railway Association. The wheels for which designs have been made, the standard for maximum load and estimated weight of the wheels are given below.

DIAMETER OF WHEEL, IN.	STANDARD FOR MAXIMUM LOAD PER WHEEL, LB.	ESTIMATED WEIGHT, LB.
24	6 000	320
24	9 000	360
24	12 000	400
24	16 000	440
26	6 000	360
26	9 000	410
26	12 000	460
26	16 000	510

DIAMETER OF WHEEL, IN.	STANDARD FOR MAXIMUM LOAD PER WHEEL, LB.	ESTIMATED WEIGHT, LB.
28	6 000	410
28	9 000	460
28	12 000	510
28	16 000	560
30	6 000	485
30	9 000	530
30	12 000	575
30	16 000	615
33	11 875	650
33	16 500	700
33	21 125	750
33	26 250	850
36	12 000	740
36	16 000	800
36	20 000	860
36	25 000	980
39	16 000	875
39	20 000	950
39	25 000	1 100
42	16 000	1 000
42	20 000	1 075
42	25 000	1 225

STANDARD SPECIFICATIONS
FOR
MALLEABLE CASTINGS[1]

Serial Designation: A 47 – 27

These specifications are issued under the fixed designation A 47; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ADOPTED, 1904; REVISED, 1915, 1919, 1924, 1927.

Scope.

1. These specifications cover malleable castings for railroad, motor vehicle, agricultural implement, and general machinery purposes.

MANUFACTURE

Process.

2. The castings shall be produced by either the air-furnace, open-hearth, or electric-furnace process.

PHYSICAL PROPERTIES AND TESTS

Tension Tests.

3. (*a*) The tension test specimens specified in Section 5 shall conform to the following minimum requirements as to tensile properties:

Tensile strength, lb. per sq. in.	50 000
Yield point, lb. per sq. in., minimum	30 000
Elongation in 2 in., per cent	10.0

(*b*) The yield point may be determined by the drop of the beam of the testing machine or by the divider method.

Special Tests.

4. (*a*) All castings, if of sufficient size, shall have cast thereon test lugs of a size proportional to the thickness of the casting, but not exceeding $\frac{5}{8}$ by $\frac{3}{4}$ in. in cross-section. On castings which are 24 in. or over in length, a test lug shall be cast near each end. These test lugs shall be attached to the casting at such a point that they will not interfere with the assembling of the castings, and may be broken off by the inspector.

(*b*) If the purchaser or his representative so desires, a casting may be tested to destruction. Such a casting shall show good, tough malleable iron.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-7 on Malleable Castings.

Tension Test Specimens.

5. (*a*) Tension test specimens shall be of the form and dimensions shown in Fig. 1. Specimens whose mean diameter at the smallest section is less than $\frac{9}{32}$ in. will not be accepted for test.

(*b*) A set of three tension test specimens shall be cast from each melt, without chills, using heavy risers of sufficient height to secure sound bars. The specimens shall be suitably marked for identification with the melt. Each set of specimens so cast shall be placed in some one oven containing castings to be annealed.

Number of Tests.

6. (*a*) After annealing, three tension test specimens shall be selected by the inspector as representing the castings in the oven from which these specimens are taken.

(*b*) If the first specimen conforms to the specified requirements, or if, in the event of failure of the first specimen, the second and third specimens conform to the requirements, the castings in that

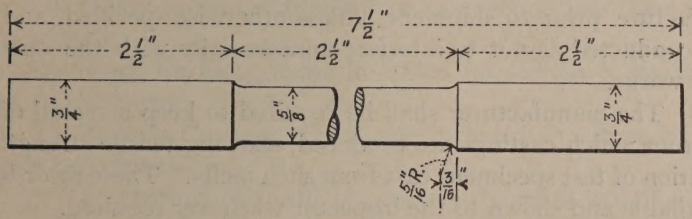

FIG. 1.

oven shall be accepted, except that any casting may be rejected if its test lug shows that it has not been properly annealed. If either the second or third specimen fails to conform to the requirements, the entire contents of that oven shall be rejected. In case one of the retest specimens contains a flaw which results in the failure of the bar to meet the specifications, at the discretion of the inspector additional test specimens from the same oven may be tested, or test specimens may be cut from castings.

Re-annealing.

7. Any castings rejected for insufficient annealing may be re-annealed once. The re-annealed castings shall be inspected and if the remaining test lugs, or castings broken as specimens, show the castings to be thoroughly annealed, they shall be accepted; if not, they shall be finally rejected.

WORKMANSHIP AND FINISH

Workmanship.

8. The castings shall conform substantially to the patterns or drawings furnished by the purchaser, and also to gages which may be specified in individual cases. The castings shall be made in a workmanlike manner. A variation of $\frac{1}{8}$ in. per ft. will be permitted.

Finish. 9. The castings shall be free from injurious defects.

MARKING

Marking. 10. The manufacturer's identification mark and the pattern numbers assigned by the purchaser shall be cast on all castings of sufficient size, in such positions that they will not interfere with the service of the castings.

INSPECTION AND REJECTION

Inspection. 11. (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the castings ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the castings are being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

(*b*) The manufacturer shall be required to keep a record of each melt from which castings are produced, showing tensile strength and elongation of test specimens cast from such melts. These records shall be available and shown to the inspector whenever required.

Rejection. 12. Castings which show injurious defects subsequent to their acceptance at the manufacturer's works may be rejected, and, if rejected, shall be replaced by the manufacturer free of cost to the purchaser.

STANDARD SPECIFICATIONS
FOR
GRAY-IRON CASTINGS[1]

Serial Designation: A 48 – 18

These specifications are issued under the fixed designation A 48; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ADOPTED, 1905; REVISED, 1918.

Scope.

1. These specifications cover three classes of gray-iron castings, as follows:

(*a*) *Light Castings*, those having any section less than ½ in. in thickness;

(*b*) *Heavy Castings*, those in which no section is less than 2 in. in thickness;

(*c*) *Medium Castings*, those not included in either of the above two classes.

Basis of Purchase.

2. The tension test will be made only when specified by the purchaser and at his expense.[2]

MANUFACTURE

Process.

3. The castings shall be made by the cupola process, unless furnace iron is specified.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

4. (*a*) Drillings taken from the fractured end of the transverse test bars shall conform to the following requirements as to sulfur:

Light castings	not over 0.10 per cent.
Medium castings	" " 0.10 "
Heavy castings	" " 0.12 "

(*b*) One sulfur determination shall be made for each mold of test bars cast, in accordance with the Standard Methods of Sampling and Chemical Analysis of Pig and Cast Iron (Serial

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-3 on Cast Iron.

[2] It is recommended by the committee that the tension test shall not be made, for the reason that cast iron is almost devoid of elasticity and hence any deviation from an absolutely straight pull in commercial testing machines yields defective results.

Designation: A 64) of the American Society for Testing Materials.[1] In case of dispute, the standards of the U. S. Bureau of Standards shall be used for comparison.

PHYSICAL PROPERTIES AND TESTS

Transverse Tests.

5. (*a*) The transverse test specimens (arbitration test bars) specified in Section 7 (*a*), when placed horizontally upon supports 12 in. apart and tested under a centrally applied load, shall conform to the following minimum requirements, interpreted in accordance with Section 9:

	Class of Casting.		
	Light.	Medium.	Heavy.
Load at center, lb	2 500	2 900	3 300
Deflection at center, in	0.10	0.10	0.10

(*b*) The rate of application of the load shall be such that a central deflection of 0.10 in. is produced in from 20 to 40 seconds.

Tension Tests.

6. When tension tests are specified, the tension test specimen shall conform to the following minimum requirements as to tensile strength:

Light castings	18 000 lb. per sq. in.
Medium castings	21 000 " "
Heavy castings	24 000 " "

Test Specimens.

7. (*a*) *Arbitration Test Bar.*—The form and dimensions of the mold for the arbitration test bar shall be in accordance with Fig. 1. The bottom of the bar shall be $\frac{1}{16}$ in. smaller in diameter than the top, to allow for draft and for the strain of pouring. The pattern shall not be rapped before withdrawing. The flask shall be rammed up with green molding sand, a little damper than usual, well mixed and put through a No. 8 sieve, with a mixture of 1 to 12 bituminous facing. The mold shall be rammed evenly and fairly hard, thoroughly dried, and not cast until it is cold. The test bar shall not be removed from the mold until cold enough to be handled. It shall not be rumbled or otherwise treated, being simply brushed off before testing.

(*b*) *Tension Test Specimen.*—When tension tests are specified, the tension test specimen shall be turned from any of the broken pieces of the transverse test specimens, and shall conform to the dimensions shown in Fig. 2.

Number of Tests.

8. (*a*) Two sets of two arbitration test bars each shall be cast from each melt, one set from the first and the other set from the last iron going into the castings. Where the melt

[1] See p. 448.

exceeds 20 tons, an additional set of two bars shall be cast for each additional 20 tons or fraction thereof. In case of a change of mixture during the melt, one set of two bars shall also be cast for every mixture other than the regular one. Each set of two bars shall be cast in a single mold.

(*b*) All arbitration test bars cast shall be tested as specified in Section 5 (*a*).

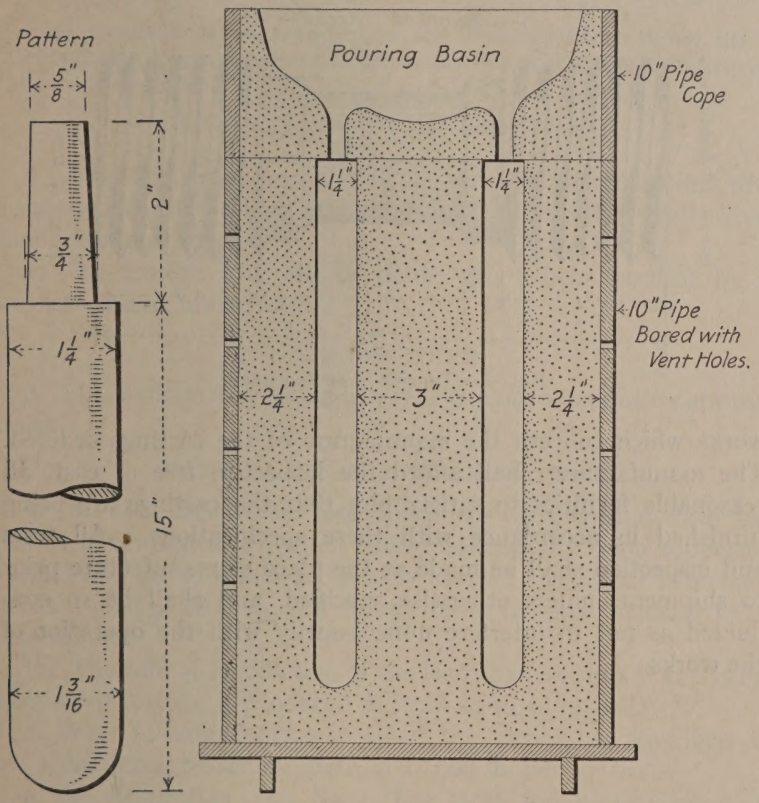

FIG. 1.—Mold for Arbitration Test Bar.

Requirements.

9. One arbitration test bar of each set cast shall conform to the requirements specified in Section 5 (*a*); otherwise the castings represented by such bars shall be rejected.

WORKMANSHIP AND FINISH

Finish.

10. The castings shall be true to pattern, and free from cracks, flaws and excessive shrinkage. In other respects they

shall conform to whatever points may be specially agreed upon between the manufacturer and the purchaser.

INSPECTION

Inspection. 11. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's

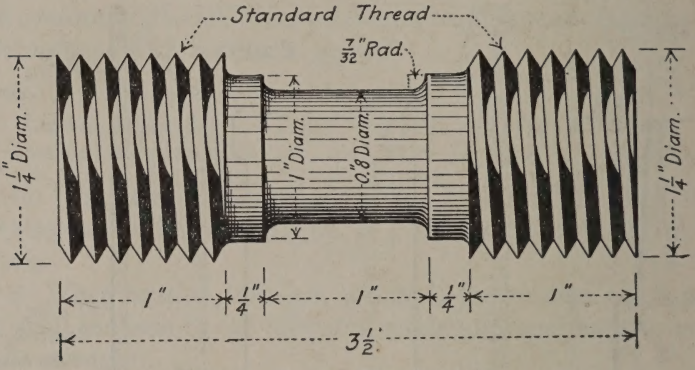

FIG. 2.—Tension Test Specimen.

works which concern the manufacture of the castings ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the castings are being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

STANDARD SPECIFICATIONS
FOR
HIGH-TEST GRAY-IRON CASTINGS[1]

Serial Designation: A 88 – 24

These specifications are issued under the fixed designation A 88; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1922; ADOPTED, 1924.

Scope.

1. These specifications cover all classes of gray-iron castings which are required to have a high strength, including those generally known as semi-steel castings.

Basis of Purchase.

2. The tension test will be made only when specified by the purchaser and at his expense.

MANUFACTURE

Process.

3. The castings may be made by the cupola, or any other approved process.

PHYSICAL PROPERTIES AND TESTS

Transverse Tests.

4. (*a*) The transverse test specimens (arbitration test bars) specified in Section 6 (*a*), when placed horizontally upon supports 12 in. apart and tested under a centrally applied load, shall withstand a minimum load of 3800 lb. and deflect under this load at least 0.12 in. at the center.

(*b*) The rate of application of the load shall be such that a central deflection of 0.10 in. is produced in from 20 to 40 seconds.

Tension Tests.

5. When tension tests are specified, the tension test specimen shall show a minimum tensile strength of 28,000 lb. per sq. in.

Test Specimens.

6. (*a*) *Arbitration Test Bar.*—The form and dimensions of the mold for the arbitration test bar shall be in accordance with Fig. 1. The bottom of the bar shall be $\frac{1}{16}$ in. smaller in diameter than the top, to allow for draft and for the strain of pouring. The pattern shall not be rapped before withdrawing. The flask shall be rammed up with green molding sand, a little damper than usual, well mixed and put through a No. 8 sieve, with a mixture of 1 to 12 bituminous facing. The mold shall be rammed evenly and fairly hard, thoroughly dried,

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-3 on Cast Iron.

and not cast until it is cold. The test bar shall not be removed from the mold until cold enough to be handled. It shall not be rumbled or otherwise treated, being simply brushed off before testing.

(*b*) *Tension Test Specimen.*—When tension tests are specified, the tension test specimen shall be turned from any of the broken pieces of the transverse test specimens, and shall conform to the dimensions shown in Fig. 2.

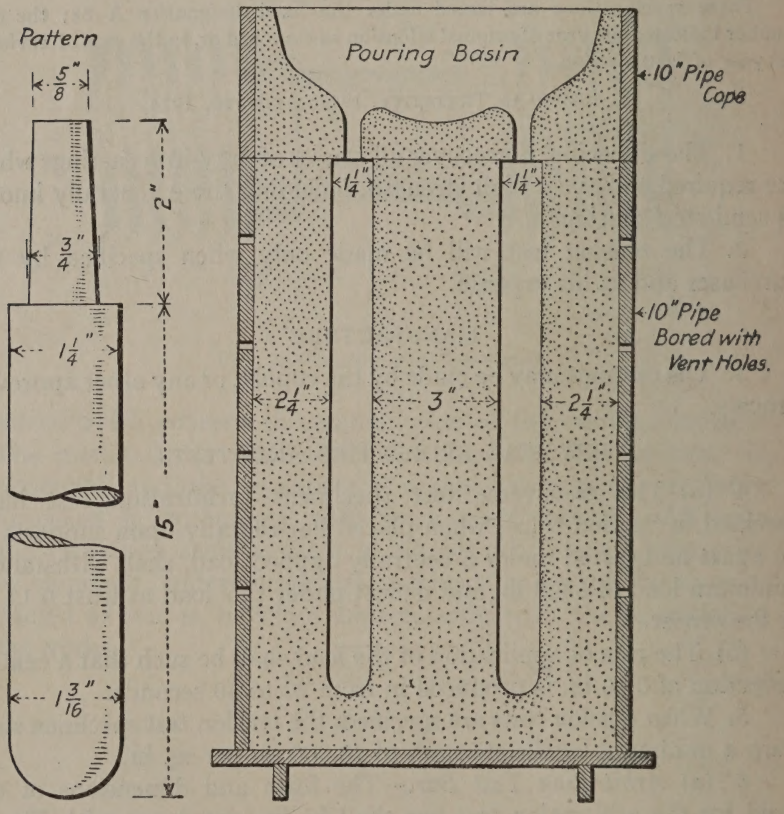

FIG. 1.—Mold for Arbitration Test Bar.

Number of Tests.

7. (*a*) Two sets of two arbitration test bars each shall be cast from each melt, one set from the first and the other set from the last iron going into the castings. Where the melt exceeds 20 tons, an additional set of two bars shall be cast for each additional 20 tons or fraction thereof. In case of a change of mixture during the melt, one set of two bars shall also be cast for every mixture other than the regular one. Each set of two bars shall be cast in a single mold.

When a large casting is made for which test bars are required, the test bar shall be cast from the same ladle of iron used to pour the casting. If two ladles are used for pouring the casting, the iron for the test bars shall be poured from a ladle of iron caught between the pouring of these two ladles. In either case the test bars shall be poured at as near as practical the same temperature at which the casting is poured.

(*b*) All arbitration test bars cast shall be tested as specified in Section 4 (*a*).

Requirements.

8. One arbitration test bar of each set cast shall conform to the requirements specified in Section 4 (*a*); otherwise the castings represented by such bars shall be rejected.

WORKMANSHIP AND FINISH

Finish.

9. The castings shall be true to pattern, and free from gas holes, cracks, flaws and excessive shrinkage. In other respects they shall

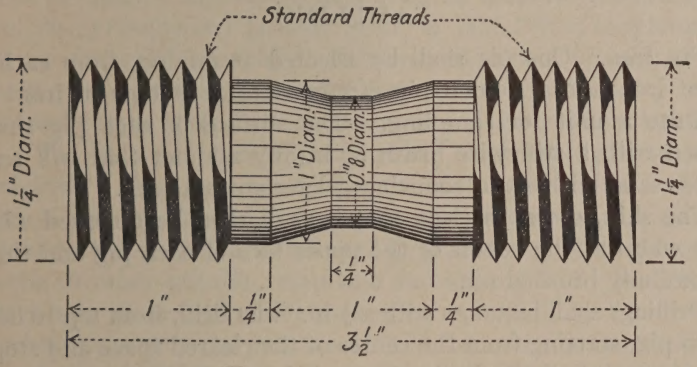

FIG. 2—Tension Test Specimen.

conform to whatever points may be specially agreed upon between the manufacturer and the purchaser.

INSPECTION

Inspection.

10. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the castings ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the castings are being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

STANDARD METHODS OF SAMPLING AND CHEMICAL ANALYSIS OF PIG AND CAST IRON[1]

Serial Designation: A 64 – 27

These methods are issued under the fixed designation A 64; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ADOPTED, 1916; REVISED, 1927.

SAMPLING

Pig Iron.—One pig shall be selected at random from each four tons of iron and ten such pigs (representing 40 tons of iron) shall constitute a unit for sampling. The surface of each pig shall be cleansed with a stiff wire brush or in any manner that will remove all loose sand without introducing deleterious matter.

The skin, down to clean metal, shall then be removed with an emery wheel at the center of the upper face of each pig and the surface carefully brushed off.

Drillings shall be taken with a $\frac{1}{4}$-in. twist drill, from top to bottom of each pig, starting from the center of the cleared space and stopping when the point of the drill appears below. One hole only shall be bored in each pig.

Suitable precautions shall be taken to prevent the escape of fine particles during the drilling, To this end a disk of clean sheet metal shall be clamped upon the pig after the skin has been removed. This disk shall have a hole in its center just large enough to receive the drill. Most of the drillings should then accumulate on top of the disk and can be brushed off after the drill is withdrawn. The pig shall then be turned bottom side up over any suitable receptacle for collecting what may have remained in the drill hole.

Castings.—In accordance with the Standard Specifications for Gray-Iron Castings (Serial Designation: A 48) of the American Society for Testing Materials,[2] three test bars, 1.2 in. in diameter,

[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee A-3 on Cast Iron.

[2] See p. 441.

shall be cast in sand from each heat at the beginning and again at the end of the pouring.

One bar from each set having been broken, one end of each next to the fracture shall be thoroughly cleaned and the outer skin removed for a sufficient distance from the fracture and down to clean metal. Chips shall then be taken by means of a lathe or milling machine across the whole face of the bar and until not less than 100 g. weight has been collected. The same amount shall be taken from each bar. The bar shall be so clamped as to permit the attachment or use of any suitable device for collecting every part of the sample and the machine shall be run slowly enough to reduce to a minimum the danger of loss of fine particles.

Subsequent Treatment of Sample from both Pig and Castings.—In the determination of total and graphitic carbon, and in the case of check analyses on the other constituents, the following precautions shall be taken: The entire unit shall be weighed and then sifted on No. 80 (177-micron) (and if need be No. 120 (125-micron)) tight-fitting sieves (with cover).[1] The finer sieve need be used only in case the particles passing the coarse sieve are not sufficiently uniform in size and shape to meet the requirements of the treatment that follows.

The two (or three) portions so obtained shall be separately weighed. Each one shall then be thoroughly mixed without any loss of material and divided by weight into two (or three) exactly equal portions, each of which shall be placed in a clean, glass-stoppered bottle or other suitable receptacle and appropriately labeled. Of the three sets of the subdivided samples, one shall be retained by the works, one sent to the purchaser's chemist and the third reserved.

Before weighing out for analysis, the contents of each bottle shall be thoroughly mixed and each portion used for analysis shall be made up of the two (or three) partial samples in the same proportion which they bear to the gross sample. Thus, if the gross sample, weighing, say, 500 g., has been separated into portions weighing 400, 80, and 20 g., the amounts of each that must be weighed to yield a 2 g. portion for analysis are 1.6 g., 0.32 g., and 0.08 g., respectively.

As a general rule the very fine material is richest in carbon, the coarse material next, while the intermediate sizes are the poorest. For routine analyses, the aim should be to obtain the iron in as small particles as possible, as for example by milling. In such case, the samples for graphite and carbon may be taken by forming a cone,

[1] For detailed specifications for these sieves, see Standard Specifications for Sieves for Testing Purposes (Serial Designation: E 11) of the American Society for Testing Materials, see p. 789.

flattening it out, and taking small dabs with a spatula from at least ten representative positions for each weighed portion. Less care is needed in taking portions for the determinations of the other constituents, grab samples from the container after gentle tumbling is satisfactory.

METHODS OF CHEMICAL ANALYSIS

In all of the following methods it is suggested that the analyst check the methods and his technique against Bureau of Standards standard samples of cast iron, or irons that have been standardized in comparison with these, except that in the case of analyses on the iron of chilled car wheels, the method and technique shall be checked against standard analyzed samples of wheel iron prepared by the Association of Manufacturers of Chilled Car Wheels.

Permissible Variations in Analyses of Cast Iron.—The following tabulation shows the variations that may occur between the results obtained by two good laboratories in the analysis of a proper sample of cast iron by the umpire method:

	Per Cent
Total Carbon	0.05 + (0.01 × per cent carbon found)[a]
Graphitic Carbon	0.10
Combined Carbon	0.10
Manganese	0.03
Phosphorus, alkalimetric or gravimetric	0.003 + (0.02 × per cent phosphorus found)
Sulfur, gravimetric	0.005
Sulfur, evolution	0.010[b]
Silicon	0.05

[a] For example, with iron containing 3 per cent carbon, this represents 0.08 per cent.

[b] This will vary, depending on whether or not the sample is annealed before test, or the manner in which the titre of the solution is obtained.

DETERMINATION OF TOTAL CARBON BY THE DIRECT-COMBUSTION METHOD

The method of direct combustion of the metal in oxygen is recommended, the carbon dioxide obtained being absorbed in soda-asbestos with suitable purifying and protecting trains following the furnace. Owing to the diversity of apparatus by which correct results may be obtained in the determination of carbon, the recommendations are intended more to indicate what is acceptable than to prescribe definitely what shall be used.

APPARATUS AND REAGENTS

Material for Lining Boats.—Alundum, "RR Alundum, alkali-free, specially prepared for carbon determination," as supplied by dealers is suitable and is recommended. The 90-mesh or finer grades are used. Low-silica chrome ore, properly sized and freed from materials causing a blank, may also be employed. Freedom from alkali or alkaline earth metals, or carbon as carbonates or in other form, must be established before the above compounds are used as a lining material. Quartz sand owing to its liability to fuse or to slag with the oxides of iron, causing bubbles of gas to be inclosed, is objectionable. Aluminum oxide, made by calcining alum or otherwise, often contains sulfate not easily destroyed, or may contain objectionable substances of an alkaline nature.

Catalyzers.—Suitable catalyzers are asbestos, copper oxide, platinized quartz or asbestos, or platinum gauze. One of these should be used in the forward part of the combustion apparatus, as well as in the preheater preceding the combustion tube (see below). Platinized materials sometimes give off volatile substances on heating, and whatever material is used should not be subject to this defect.

Accelerators.—Millings of ingot iron or other iron with 0.01 to 0.02 per cent of carbon are the most satisfactory aids in the combustion of large drillings.

Combustion Apparatus.—Any apparatus heated by electricity or gas which will bring the sample to a temperature of 950 to 1100° C. may be used. Combustion tubes may be porcelain, glazed on one or both sides, quartz or platinum. Quartz is liable to devitrification when used continuously at temperatures above 1000° C., and may then become porous. Tubes 30 in. long and $1\frac{1}{4}$ in. inside diameter drawn out at one end are convenient. This length permits at least 12 in. of the exit end to project from the furnace, the drawn-out end allows direct connection with the absorber and the large inner diameter accommodates larger boats and small Gooch crucibles as in the Determination of Graphite.

Boats or Other Containers of Samples Being Burned.—These may be porcelain, quartz, alundum, clay, platinum or nickel, and should always receive a lining of granular alundum or any other material found to be suitable for the purpose. Nickel boats should not be made of sheet nickel containing more than 0.15 per cent of carbon. Before use, new boats should always be preheated in oxygen until no more carbon dioxide is given off. In order to prevent spattering and attack of the tube, a platinum or nickel cover open at both ends and allowing free access of oxygen, is desirable.

Purifying Train Before Combustion Apparatus.—This consists of a tower filled with soda-asbestos, soda-lime or granular sodium hydroxide preceded by a preheater when necessary.

Oxygen.—Oxygen of not less than 97 per cent purity is recommended. Endeavor should be made to obtain oxygen which gives no blank, since the correction for or elimination of this is troublesome and uncertain. For the most accurate work, particularly with low-carbon products, such as ingot iron, etc., the blank should be completely eliminated by the use of a preheater before the furnace, with a carbon-dioxide absorbent interposed between furnace and preheater.

FACTORS INFLUENCING RAPID COMBUSTION

Size of Particles of Sample.—The finer the chips (short of dust, which causes low values on a hot boat) the better, except with samples which burn too vigorously (see *Rate of Admitting Oxygen*). Particles too coarse to pass a No. 20 (840 micron) sieve are not recommended. Oil, dust, and other foreign matter should be carefully excluded.

Manner of Distributing Sample in Boat.—This is of considerable importance. With all samples, close packing in a small space is conducive to rapid combustion. In the case of samples which burn too vigorously, a satisfactory regulation may sometimes be attained by spreading the sample loosely over the lining in the boat.

Rate of Admitting Oxygen.—The rate at which oxygen is admitted is also a factor in the velocity of combustion. Assuming the combustion apparatus to be heated to the temperature range above recommended (950 to 1100° C.), it is possible, if the material is closely packed and if oxygen is admitted at too rapid a rate, that the combustion may be so violent as to cause excessive spattering of fused oxides, and such fluidity of the molten slag that the boat or other container may be injured or destroyed; therefore, a moderate rate of burning is to be sought. Sufficient oxygen, however, must be run in to insure a current of gas through the absorber at all stages of the combustion. The factors, temperature of combustion apparatus, manner of distribution of sample, and rate of admission of oxygen, can be governed so as to burn successfully irons of a very wide range of compositions in either fine or coarse particles.

Determination of Total Carbon (Carbon Dioxide Absorbed in Soda-Asbestos)

SPECIAL APPARATUS

Purifying and Protecting Trains.—This method requires a purifying train before and after the combustion furnace.

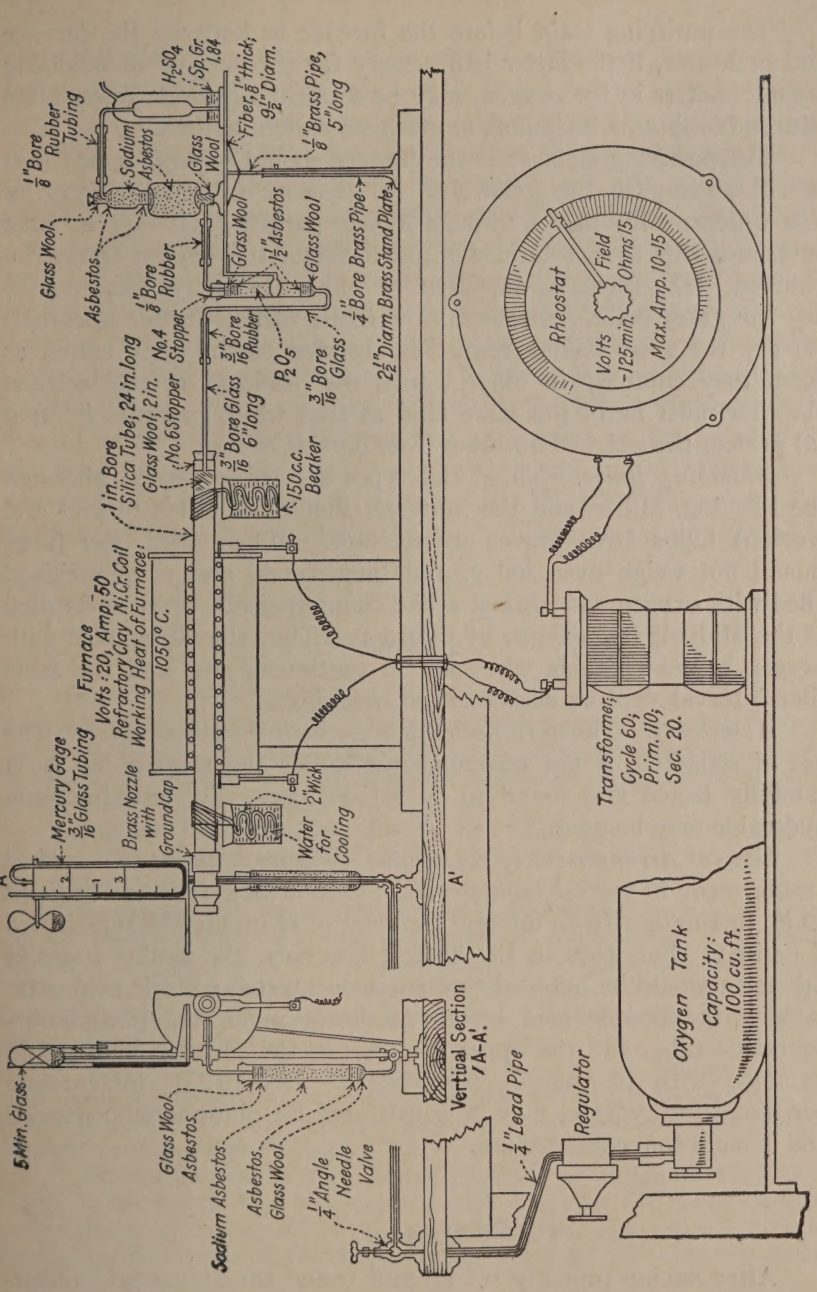

FIG. 1.—Apparatus for Determination of Carbon by the Direct-Combustion Method.

The purifying train before the furnace or between the furnace and preheater, if the latter is necessary for the purpose of oxidizing organic matter in the oxygen, may be a calcium-chloride tower filled with soda-asbestos, soda-lime or granular sodium hydroxide.

The purifying train after the furnace should be so designed that it will accomplish the following: (1) Remove impalpable oxide of iron which readily passes through loosely packed plugs of glass wool or asbestos or even solutions through which the oxygen is rapidly bubbled; (2) remove oxides of sulfur which are always formed; (3) dry the gases before entering the weighed carbon-dioxide absorber; (4) dry the gases issuing from this absorber to the same extent as when they entered; in other words, the dessicant in the weighed absorber must be of the same kind as that which precedes it; and (5) protect the weighed absorber from outside effects.

Absorbing Bulbs.—No special types are recommended although the Fleming, Miller, and the Midvale (sometimes called Stetzer and Norton) bulbs have proven satisfactory. When filled, the tubes should not weigh over 200 g. and they should always be weighed filled with oxygen and against a like counterpoise. Open bulbs such as the Midvale lose oxygen by diffusion. They should be filled with oxygen before weighing when not in continuous use, and the same time interval shall be held between weighings.

Absorbents.—The most desirable absorbent is soda-asbestos. The use of soda-lime is not recommended unless the reagent has been carefully tested and found to be satisfactory. Pulverized sodium hydroxide may be used.

General Arrangement of Apparatus.—Figure 1 presents a typical arrangement in works' laboratories. Combustion tubes as large as 30 in. in length with an internal diameter of $1\frac{1}{4}$ in. may be substituted if desired. For work of the highest accuracy, the issuing gases in this train would be bubbled through concentrated sulfuric acid saturated with chromic acid before passing through the phosphorus-pentoxide tube, and the upper chamber of the Fleming bulb would be filled with phosphorus pentoxide. "Dehydrite" (magnesium perchlorate trihydrate) may be substituted for phosphorus pentoxide and is more convenient to use.

METHOD

After having properly set up and tested the apparatus, moderately pack the desired weight of iron (in the form recommended above) on the bed material in the boat and introduce the boat into

the combustion apparatus, which has already been heated to the proper temperature. Allow the sample to heat-up for 1 to 3 minutes, depending upon the size of particles, and then admit the gas at such a rate that the gases leave the absorbents at the rate of 200 to 400 cc. per minute. The sample burns completely in 1 or 2 minutes, and all that is now necessary is to sweep all of the carbon dioxide into the absorption bulb. Regulate the rate of flow of the oxygen between 200 and 400 cc. per minute and continue the flow for 10 minutes. Withdraw the absorption tube while filled with oxygen, place in the balance case for ten minutes, open momentarily and weigh against a like tube used as a counterpoise. The increase in weight represents carbon dioxide which when multiplied by 27.27 and divided by the weight of the sample represents the percentage of total carbon in the iron. Remove the boat from the tube and examine the fusion for evidences of incomplete combustion. If the drillings are not thoroughly fused in a solid pig the determination must be rejected.

NOTES

1. Oxides of sulfur cause positive errors when no provision is made for their removal. Sulfur trioxide can be almost entirely removed by interposing some baffle which condenses it, such as asbestos, phosphorus pentoxide, or sulfuric acid. Sulfur dioxide is not so easily removed; the most satisfactory medium is concentrated H_2SO_4 saturated with chromic acid.

2. The oxides of sulfur which are fixed and accumulate in the end of the combustion tube should be periodically removed by heating the end of the tube in the hot zone of the furnace.

3. In accurate work it is desirable to include in the weighed system a dehydrating agent which will dry the escaping gas to the same degree as when it entered the system. The loss of water from a good grade of soda-asbestos may cause losses higher than 0.01 per cent carbon in ordinary combustions. In careful work it is also desirable to protect the weighed system from moisture and carbon dioxide by means of suitable end tubes.

4. Soda-asbestos is commercially known as "Ascarite" and directions for its preparation are to be found in the *Journal Industrial and Engineering Chemistry*, Vol. 8, pp. 1038–9 (1916). For the use of granular sodium hydroxide see the *Journal Industrial and Engineering Chemistry*, Vol. 13, p. 1052 (1921).

5. In some laboratories the absorbing bulbs are always kept in the balance case. In this case the balances are placed on the same table with the furnaces and each balance usually contains two absorbing bulbs which are connected by short lengths of rubber tubing to glass tubes extending out of the balance and connecting with a pair of furnaces.

6. The operator should occasionally test the apparatus and his technique by means of the irons noted in the introductory paragraph or irons which have been standardized in comparison with these.

DETERMINATION OF GRAPHITE

SOLUTIONS REQUIRED

Dilute Nitric Acid (sp. gr. approximately 1.20).—Mix 380 cc. of HNO_3 (sp. gr. 1.42) and 620 cc. of distilled water.

Ignited Asbestos.—Gently ignite prepared asbestos under oxidizing conditions until all carbonaceous matter has been consumed. Prepared asbestos is asbestos that has been digested with HCl and then thoroughly washed with water.

Potassium Hydroxide Solution (sp. gr. approximately 1.10).—Dissolve 120 g. of stick KOH in 1000 cc. of water.

Dilute Hydrochloric Acid (1:20).—Mix 50 cc. of HCl (sp. gr. 1.19) and 1000 cc. of water.

METHOD

Dissolve 1 to 3 g. of the sample in 50 cc. of HNO_3 (sp. gr. 1.20) and heat gently on the steam bath until action ceases. If silicic acid separates add 5 cc. of HF to facilitate filtration. Collect the residue conveniently on *ignited asbestos* by the use of suction and fused-silica Gooch crucibles of such diameter as will go in the combustion tube. Wash the residue thoroughly with hot water, then with a hot solution of KOH (sp. gr. 1.10), then with dilute HCl (1:20) and finally with hot water. Dry at a temperature not to exceed 150° C. and determine the graphite by direct combustion in the apparatus used for the determination of total carbon, taking care to close the combustion tube immediately after inserting the sample.

It is preferable to run the combustion at approximately 700° C. An oxidant, such as oxidized copper gauze, should be provided in the hot exit end of the tube to insure complete combustion to carbon dioxide.

DETERMINATION OF COMBINED CARBON

Direct determinations of "combined carbon" in cast iron are not satisfactory and, therefore, for the present it is recommended that the percentage of combined carbon be obtained by subtracting the percentage of graphite from the percentage of total carbon.

DETERMINATION OF MANGANESE BY THE BISMUTHATE METHOD

(REFEREE METHOD IN THE ABSENCE OF COBALT)

SOLUTIONS AND REAGENTS REQUIRED

Dilute Nitric Acid (1:3).—Mix 500 cc. of HNO_3 (sp. gr. 1.42) and 1500 cc. of distilled water.

Dilute Nitric Acid (3:97).—Mix 30 cc. of HNO_3 (sp. gr. 1.42) (free from oxides of nitrogen) and 970 cc. of distilled water.

Asbestos.—The asbestos for this work should be shredded, digested with HCl, thoroughly washed with water, then digested on the steam bath with dilute HNO_3 (1:3), and finally thoroughly washed with water, to remove chlorides and to oxidize any ferrous iron contained in the asbestos. In making the asbestos filter-pad it is advisable to have a thin bed and as much surface as possible. This insures rapid filtration, and the filter can be used until it becomes clogged with bismuthate.

Bismuthate.—The sodium bismuthate should contain at least 70 per cent of $NaBiO_3$ or 4 per cent of active oxygen and not more than 0.005 per cent of manganese. Each bottle of bismuthate should be tested for strength and manganese contents. Its strength can be determined as follows: Weigh accurately about 3 g. of the bismuthate, mix in a 100-cc. graduated flask with a solution of 20 g. of KI in 30 cc. of water and shake well. Add 20 cc. of HCl, (sp. gr. 1.19), stopper the flask, allow to stand for one hour in the dark, and dilute to the mark. Mix and titrate 10 cc. of the solution with 0.1 *N* sodium thiosulfate, using starch as an indicator. One cubic centimeter of 0.1 *N* thiosulfate equals 0.0008 g. of active oxygen. Determine the manganese content by boiling 3 g. of bismuthate with 30 cc. of dilute HNO_3 (1:3) and matching the color by adding standard permanganate solution to a like amount of acid.

Ferrous Ammonium Sulfate Solution.—Dissolve 12 g. of ferrous ammonium sulfate in a cold mixture of 950 cc. of distilled water and 50 cc. of H_2SO_4 (sp. gr. 1.84).

Standard Potassium Permanganate Solution.—Dissolve 1 g. of $KMnO_4$ in 1000 cc. of distilled water. Allow it to stand for at least one week and then filter through purified asbestos. Standardize against the Bureau of Standards standard sodium oxalate as follows: In a 200-cc. beaker; dissolve 0.1 g. of sodium oxalate in 75 to 100 cc.

of hot water (80 to 90° C.) and add 5 cc. of H_2SO_4 (1:1). Titrate at once with the permanganate solution, stirring the liquid vigorously and continuously. The permanganate must not be added more quickly than 10 to 15 cc. per minute, and the last 0.5 to 1 cc. must be added dropwise, with particular care to allow each drop to be fully decolorized before the next is introduced. The excess of permanganate used to cause an end-point color must be estimated by matching the color in another beaker containing the same bulk of acid and hot water. The temperature of the solution should not be below 60° C. by the time the end point is reached.

Standard Sodium Arsenite Solution.—Dissolve 2 g. of sodium arsenite in distilled water, filter if necessary, and dilute to one liter. Standardize against the standard permanganate solution by titrating 10-cc. portions under the acidity and dilution conditions that obtain in the method. A clear green color free from brownish or purplish tints will be found a satisfactory and reproducible end point. The solution can also be standardized against a standard cast iron or steel.

METHOD

Dissolve 1.000 g. of the sample in 25 cc. of dilute HNO_3 (1:3) and boil to expel oxides of nitrogen. Cool, filter, and wash with 25 to 50 cc. of dilute HNO_3 (1:3). Add 0.5 g. of sodium bismuthate to the filtrate, heat to boiling and boil for at least 3 minutes. Clear the solution if permanganic acid or manganese dioxide is present by adding a few drops of a saturated solution of sulfur dioxide or other suitable reducing agent free from manganese and chlorides, and boil to expel oxides of nitrogen and sulfur. Cool to 15° C., add an excess of sodium bismuthate, agitate and let stand for a few minutes. Add 50 cc. of 3-per-cent HNO_3 (free from nitrous acid) and filter through asbestos. Wash with HNO_3 (3-per-cent) until the washings run through colorless. The filtrate must be clear and absolutely free from particles of bismuthate. Titrate by either method (*a*) or (*b*) as follows:

(*a*) *Ferrous Sulfate—Permanganate Titration.*—Add from a burette or pipette 10 to 50 cc. (depending on the amount of permanganic acid) of ferrous ammonium sulfate solution and then titrate with the standard $KMnO_4$ solution. In exactly the same manner carry through a blank determination using the same amounts of acid and bismuthate as was done with the regular sample. Finally add the exact volume of ferrous ammonium sulfate solution which was employed and titrate with the standard $KMnO_4$ solution. The difference between the volumes required in the two titrations represents the manganese in the sample.

(*b*) *Arsenite Titration.*—Titrate immediately with the standard sodium arsenite solution to the clear green color used as an end point in the standardization of the solution. In this titration, permanganic acid does not react in accordance with the ratio Mn_2O_7:2MnO. Consequently the theoretical titre of the arsenite solution can not be employed.

DETERMINATION OF MANGANESE BY THE PERSULFATE METHOD (ROUTINE AND IN THE PRESENCE OF COBALT)

SOLUTIONS REQUIRED

Dilute Nitric Acid (*sp. gr. approximately 1.20*).—Mix 380 cc. of HNO_3 (sp. gr. 1.42) and 620 cc. of distilled water.

Silver Nitrate (*0.133-per-cent*).—Dissolve 1.33 g. of $AgNO_3$ in 1000 cc. of distilled water.

Ammonium Persulfate Solution (*10-per-cent*).—Prepare as needed by dissolving 10 g. of the salt in 100 cc. of distilled water. The salt should show at least 80 per cent of persulfate by test. The pure salt ordinarily contains 95 per cent of persulfate. For method of test see Solutions Required in Determination of Small Amounts of Chromium.[1]

Sodium Chloride (*0.2-per-cent*).—Dissolve 2 g. of NaCl in 1000 cc. of distilled water.

Standard Sodium Arsenite.—Dissolve 0.8 g. of sodium arsenite in distilled water, filter if necessary; dilute to one liter and standardize against measured portions of a standard permanganate solution which have been reduced by hydrogen peroxide or ferrous sulfate, that is free from manganese and then treated as in the method to be described, or against standard samples of iron.

METHOD

In a small Erlenmeyer flask or large test tube (8 by 1 in.) dissolve 0.1 to 0.3 g. of iron, depending on the manganese content of the sample, in 15 cc. of dilute HNO_3 (sp. gr. 1.20) and boil to expel oxides of nitrogen. Add 5 cc. of $(NH_4)_2S_2O_8$ solution (10-per-cent) and heat several minutes to oxidize the combined carbon. Remove graphite by filtration through a small rapid paper, and wash the paper with 15 cc. of $AgNO_3$ solution (0.133-per-cent) and a small amount of water. If a tube is used, add 10 cc. of the $(NH_4)_2S_2O_8$

[1] See p. 470.

solution (10-per-cent) and heat in the water bath until the color develops. If a flask is employed, bring the solution to boiling, add 10 cc. of the persulfate solution and then set aside in a warm place until the color develops. When the full color has developed, cool the solution in running water, transfer to a 250-cc. beaker and dilute to a volume of 75 cc. Add 10 cc. of NaCl solution (0.2-per-cent) and titrate with standard arsenite solution.

NOTES

In the arsenite titration, permanganic acid does not react in accordance with the ratio Mn_2O_7: 2 MnO, but more nearly as indicated by the ratio Mn_2O_7: Mn_2O_3. Consequently, the theoretical titre of the arsenite can not be used and the manganese titre must be obtained by titration of material of known manganese content and under the conditions that obtain in the method.

The persulfate oxidation requires careful attention; the solution must not be too acid and sufficient $AgNO_3$ must be present (about 15 times as much $AgNO_3$ as Mn). Consequently, in irons of high manganese content the amount of $AgNO_3$ and NaCl should be increased.

No MnO_2 must be separate on heating after the first addition of persulfate for this would be lost when the solution is filtered.

DETERMINATION OF PHOSPHORUS BY WEIGHING AS MAGNESIUM PYROPHOSPHATE (REFEREE METHOD)

SOLUTIONS REQUIRED

Dilute Nitric Acid (1:1).—Mix equal parts of HNO_3 (sp. gr. 1.42) and water.

Dilute Hydrochloric Acid (1:1).—Mix equal parts of HCl (sp. gr. 1.19) and water.

Dilute Hydrochloric Acid (1:20).—Mix 50 cc. of HCl (sp. gr. 1.19) and 1000 cc. of water.

Dilute Ammonium Hydroxide (1:2).—Mix 300 cc. of NH_4OH (sp. gr. 0.90) and 600 cc. of distilled water.

Dilute Ammonium Hydroxide (1:20).—Mix 100 cc. of NH_4OH (sp. gr. 0.90) and 2000 cc. of distilled water.

Dilute Nitric Acid (2:100).—Mix 20 cc. HNO_3 (sp. gr. 1.42) and 1000 cc. of distilled water.

Ammonium Molybdate.—

Solution No. 1.—Place in a beaker 100 g. of 85-per-cent molybdic acid, mix it thoroughly with 240 cc. of distilled water, add 140 cc. of NH_4OH (sp. gr. 0.90), filter, and add 60 cc. of HNO_3 (sp. gr. 1.42).

Solution No. 2.—Mix 400 cc. of HNO_3 (sp. gr. 1.42) and 960 cc. of distilled water.

When the solutions are cold, add Solution No. 1 to Solution No. 2, stirring constantly; then add 0.1 g. of ammonium phosphate dissolved in 10 cc. of distilled water. Let stand at least 24 hours and filter the solution.

Magnesia Mixture.—Dissolve 50 g. of $MgCl_2 \cdot 6H_2O$ and 100 g. of NH_4Cl in 200 cc. of distilled water, and then add 5 cc. of NH_4OH (sp. gr. 0.90). Let stand overnight, filter if a precipitate appears, make just acid with HCl and dilute to 1000 cc. with water.

METHOD

Dissolve 1 to 3 g. of the sample in a covered casserole in 30 cc. of dilute HNO_3 (1:1). When solution is complete add 10 cc. of dilute HCl (1:1), evaporate to dryness, and bake for 15 to 20 minutes on the hot plate. Cool, drench the residue with concentrated HCl, dilute to 50 cc. with hot water, and warm until the salts are in solution. Filter without delay, wash with dilute HCl (1:20), and evaporate the filtrate to syrupy consistency. In the meantime, place the paper containing graphite and silica in a platinum crucible, burn off the carbon, cool, and add 5 to 10 drops of concentrated HCl and 1 to 2 cc. of HF. Evaporate just to dryness, take up any residue in 5 cc. of concentrated HCl, and add the solution to the main solution which is being evaporated. When the solution is of syrupy consistency, transfer it to a 300-cc. Erlenmeyer flask by alternate washing with dilute HNO_3 (1:1) and hot water, using not more than 30 cc. of the former and 70 cc. of the latter. Heat to boiling, add NH_4OH until a permanent precipitate has formed, dissolve in dilute HNO_3 (1:1) and then add 100 cc. of molybdate reagent. Shake for 10 minutes and allow to stand not less than 6 hours.

Filter on a paper of close texture, and wash the flask and the precipitate with not more than 50 cc. of cold dilute HNO_3 (1:99). Set the filtrate and washings aside after thorough mixing. If further separation of phosphomolybdate occurs in 4 hours, recover the precipitate and determine its phosphorus content. Dissolve the precipitate on the filter and in the flask in 20 cc. of dilute NH_4OH (1:1) to which has been added 2 g. of citric acid, catch the solution in a 250-cc. beaker, wash the filter several times with dilute NH_4OH (1:20), then with hot water, and finally several times with dilute HCl (1:20). If the ammoniacal solution of the phosphomolybdate is not clear at this point, heat it to boiling, filter through the same paper, wash the paper with hot water, ignite in a small platinum

crucible, fuse any residue with as little carbonate as possible (not over 0.5 g.), extract the cooled melt with hot water, filter and add the water solution to the ammoniacal solution.

Render the ammoniacal solution acid with HCl, add 20 cc. of magnesia mixture, then add NH_4OH (sp. gr. 0.90) cautiously until a crystallin precipitate appears. From this point proceed very slowly until the solution is alkaline and then add 5 cc. of NH_4OH in excess. The volume of the solution at this point should not exceed 100 cc. Allow the solution to stand in a cool place for not less than 6 hours. Filter, and wash the precipitate moderately with dilute NH_4OH (1:19). Dissolve the precipitate on the filter in 25 cc. of dilute HCl (1:1), catching the solution in the original beaker. Wash the filter thoroughly with dilute HCl (1:20). Add 0.5 to 1 g. of ammonium bromide and boil the HCl solution to a volume of 5 to 10 cc. (but not to dryness) to eliminate small amounts of arsenic. Precipitation with hydrogen sulfide can be substituted for the evaporation with hydrobromic acid and is desirable in case much arsenic is present. Dilute to a volume of 50 to 75 cc., add 0.1 to 0.2 g. of citric acid, 2 to 3 cc. of magnesia mixture, make ammoniacal as above, and allow to stand in a cool place for not less than 4 hours.

Filter, wash with dilute NH_4OH (1:20) until chlorides have been removed; ignite the precipitate carefully and at as *low a temperature* as possible, until the carbon has been destroyed and the residue is white. Finally, ignite at approximately 1000° C. to constant weight. Dissolve the ignited precipitate in 10 cc. of dilute H_2SO_4 (1:4). Evaporate to fumes of sulfuric acid, dilute, filter, and wash with hot water. Ignite, weigh, treat with a few drops of HF, evaporate to dryness, ignite, and reweigh. Subtract any loss of weight from the original weight of the pyrophosphate, and calculate on the basis of this purified magnesium pyrophosphate.

DETERMINATION OF PHOSPHORUS BY THE ALKALIMETRIC METHOD (ROUTINE)

SOLUTIONS REQUIRED

Dilute Nitric Acid (sp. gr. approximately 1.135).—Mix 280 cc. of HNO_3 (sp. gr. 1.42) and 720 cc. of water.

Potassium Permanganate (1.5-per-cent).—Dissolve 15 g. of $KMnO_4$ in 1000 cc. of water.

Ammonium Bisulfite (3-per-cent).—Dissolve 30 g. of ammonium bisulfite in 1000 cc. of distilled water. This salt must be free from phosphorus.

Ammonium Hydroxide (sp. gr. 0.96).—Mix 400 cc. of NH_4OH (sp. gr. 0.90) and 600 cc. of water. The strength of this solution should be verified by hydrometer or titration.

Ammonium Molybdate Solution.—See the Determination of Phosphorus by Weighing as Magnesium Pyrophosphate (Referee Method).[1]

Potassium Nitrate (1-per-cent).—Dissolve 10 g. of KNO_3 in 1000 cc. of distilled water.

Phenolphthalein Indicator.—Dissolve 0.2 g. of phenolphthalein in 50 cc. of 95-per-cent ethyl alcohol and 50 cc. of distilled water.

Standard Sodium Hydroxide.—Dissolve 6.5 g. of purified NaOH in 1000 cc. of distilled water, add a slight excess of 1-per-cent solution of $Ba(OH)_2$, let stand for 24 hours, decant the liquid, standardize it against an iron of known phosphorus content as determined by the molybdate-magnesia method, and dilute so that 1 cc. will be equivalent to 0.01 per cent of phosphorus on the basis of a 2-g. sample. The solution may also be standardized by the use of the Bureau of Standards standard sample of Benzoic Acid and the ratio 23 NaOH to 1 P. Protect the solution from carbon dioxide by means of a soda-lime or soda-asbestos tube.

Standard Nitric Acid.—Mix 10 cc. of HNO_3 (sp. gr. 1.42) and 1000 cc. of distilled water. Titrate the solution against the standard NaOH solution using phenolphthalein as indicator and finishing the titration at the pink end point. Finally, render the acid solution equivalent to the NaOH solution by adding distilled water.

METHOD

Dissolve 0.5 to 2 g. of the sample in 50 cc. of HNO_3 (sp. gr. 1.135) and destroy organic matter by boiling with 10 cc. of a 1.5-per-cent solution of $KMnO_4$ until oxide of manganese is precipitated. Dissolve the oxide by addition of ammonium bisulfite, boil to expel the oxides of nitrogen, filter, and wash with 50 cc. of HNO_3 (sp. gr. 1.135). Add to the cool solution 40 cc. of NH_4OH (sp. gr. 0.96), 40 cc. of ammonium molybdate solution and shake for 5 minutes. Let settle and filter on a 9-cm. No. 42 Whatman or equivalent paper which had been fitted tightly in the funnel. With irons high in vanadium or titanium the solution should be allowed to settle for 2 hours. Wash the flask, precipitate, and the filter paper with 25-cc. portions of a 1-per-cent solution of KNO_3 until 10 cc. of washings will not decolorize one drop of the standard alkali plus one drop of

[1] See p. 460.

phenolphthalein. Return the paper and precipitate to the precipitating vessel, add a 2 to 5-cc. excess of standard NaOH solution and 25 cc. of water, both free from carbon dioxide, and shake or stir until the precipitate is dissolved. Dilute to from 100 to 200 cc. with water free from carbon dioxide, add 3 drops of 0.2-per-cent phenolphthalein solution, and discharge the pink color with standard acid. Finish the titration by adding standard alkali until the reappearance of the pink color. In the analysis of low phosphorus iron this titration should be corrected by a blank carried through all steps of the method.

NOTE.—With irons containing vanadium in excess of 0.05 per cent, cool the solution to 10 to 15° C. and add 1 g. of ferrous sulfate just before the addition of molybdate reagent.

DETERMINATION OF SULFUR BY THE GRAVIMETRIC METHOD (REFEREE METHOD)

SOLUTIONS REQUIRED

Dilute Hydrochloric Acid (1:99).—Mix 10 cc. of HCl (sp. gr. 1.19) and 990 cc. of water.

Barium Chloride Solution (10-per-cent).—Dissolve 100 g. of $BaCl_2 \cdot 2H_2O$ in 1000 cc. of distilled water.

Dilute Sulfuric Acid (1:1).—Carefully add while stirring 100 cc. of H_2SO_4 (sp. gr. 1.84) to 100 cc. of water.

METHOD

Dissolve the sample (4.57 g.) in 50 cc. of HNO_3 (sp. gr. 1.42) in a covered beaker or flask. Add 0.5 g. of Na_2CO_3, evaporate to dryness and bake for 1 hour on the hot plate. Add 30 cc. of HCl (sp. gr. 1.19) and repeat the evaporation and baking. Add another 30 cc. of HCl (sp. gr. 1.19) and evaporate to dryness. Add 25 cc. of HCl (sp. gr. 1.19), 25 cc. of water, 5 g. of 20 to 30-mesh zinc free from sulfur, and warm on the steam bath until the iron is reduced to ferrous chloride and the evolution of hydrogen has nearly ceased. Filter from the silica and undissolved zinc, wash with approximately 75 cc. of HCl (1-per-cent by volume), warm to 60 to 80° C. and add 10 cc. of 10-per-cent barium chloride. Let stand 18 to 24 hours, filter on a paper of close texture and discard the filtrate. Wash once or twice with cold 1-per-cent HCl and then with hot water until free from chlorides. Reserve the precipitate and evaporate the washings to

dryness. Dissolve the slight residue in 1 cc. of dilute HCl (1:1), dilute to 25 cc. with hot water, add 1 cc. of 10-per-cent $BaCl_2$ solution, and digest at the side of the steam bath for one hour. Filter on a small paper of close texture, and wash with hot water until free from chlorides. Ignite both papers in platinum and treat with one drop of H_2SO_4 (1:1) and 1 cc. of HF. Evaporate to dryness, ignite, and weigh. A blank should be carried through all steps of the determination. The corrected weight of the ignited barium sulfate multiplied by three is equal to the percentage of sulfur.

NOTE.—The solution should preferably contain not more than 2 per cent by volume of HCl at the time of the precipitation with $BaCl_2$. Ordinarily, there will be no hydrolysis of iron during the filtration and washing of the undissolved zinc or the precipitation with $BaCl_2$. Should this occur, the solution must be cleared by the addition of HCl, having due regard to the final permissible acidity.

DETERMINATION OF SULFUR BY THE GRAVIMETRIC METHOD (OPTIONAL REFEREE METHOD)

SOLUTIONS REQUIRED

Double Chloride Solution.—Dissolve 756 g. of copper potassium chloride ($CuCl_2 \cdot 2KCl \cdot 2H_2O$) in 2000 cc. of water, and add 20 0cc. of HCl (sp. gr. 1.19).

METHOD

Transfer 4.57 g. of the sample to an Erlenmeyer flask, treat with 250 cc. of the double chloride solution, and stir gently by mechanical means until all of the iron is in solution. For more rapid solution of the iron, first place the double chloride solution in a flask provided with a stopper containing inlet and outlet tubes for carbon dioxide, warm to approximately 40° C. as a stream of CO_2 is bubbled through the solution, introduce the sample, replace the stopper and continue the passage of the gas with occasional shaking of the flask to prevent clogging of the inlet tube.

When solution is complete, let settle for a moment, decant through a rapid filter and wash quickly, by decantation as much as possible, with a little hot water. Place filter paper and contents in the original flask, add 25 cc. of water, then 5 cc. of bromine and finally 5 cc. of concentrated HCl. Heat gently till free of bromine, dilute to 100 cc., filter, and wash the residue thoroughly with hot water. Precipitate

with $BaCl_2$ and finish the determination as described in the Determination of Sulfur by the Gravimetric Method (Referee Method).[1]

The results must be corrected by blanks run under the same conditions as the determination.

DETERMINATION OF SULFUR BY THE EVOLUTION METHOD (ROUTINE)

APPARATUS

Figure 2 shows a typical apparatus for this determination. A spray trap may be put in the outlet tube to prevent iron from passing over into the ammoniacal solution.

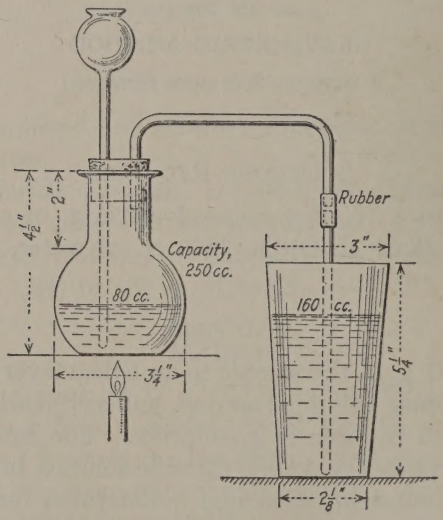

FIG. 2.—Apparatus for Determination of Sulfur by the Evolution Method.

SOLUTIONS REQUIRED

Dilute Hydrochloric Acid (1:1).—Mix 500 cc. of HCl (sp. gr. 1.19) and 500 cc. of distilled water.

Ammoniacal Cadmium Chloride.—Dissolve 10 g. of cadmium chloride in 400 cc. of distilled water and add 600 cc. of NH_4OH (sp. gr. 0.90).

[1] See p. 464.

Ammoniacal Zinc Sulfate (Optional Solution).—Dissolve 200 g. of zinc sulfate in 1080 cc. of water, and add 920 cc. of NH_4OH (sp. gr. 0.90).

Starch Solution.—To 500 cc. of boiling distilled water, add a cold suspension of 5 g. of soluble starch in 25 cc. of distilled water, cool, add a cool solution of 5 g. of NaOH in 50 cc. of distilled water, then add 15 g. of KI and mix thoroughly.

Potassium Iodate.—Dissolve 1.12 g. of KIO_3 and 12 g. of KI in 1000 cc. of distilled water. For general work the theoretical sulfur titre of this solution should be used; for specialized work on one kind of material, the solution may be standardized against like material. The theoretical titre is based on standard sodium oxalate and is obtained as follows: To 300 cc. of water in a 600 cc. flask, preferably glass-stoppered, add 10 cc. of HCl (sp. gr. 1.19) and 1 g. of KI. Cool and add 25 cc. of 0.03 *N* $KMnO_4$ solution which has been standardized against sodium oxalate. Swirl gently, stopper, and let stand for five minutes. Titrate the liberated iodine with thiosulfate solution until the color nearly fades. Then add 10 cc. of starch solution and continue the titration until the blue color is destroyed. In a new flask, repeat the experiment with the sole difference that 25 cc. of the iodate solution is substituted for the standard permanganate solution. Calculate the normality of the iodate solution, and dilute it if desired so that its normality is 0.0312, or 1 cc. is equivalent to 0.01 per cent of sulfur on a 5-g. sample. For standardization against like material, 5-g. portions of the proper standard cast iron is carried through all steps of the method. The following equations represent the reactions that are involved:

$$5\ Na_2C_2O_4 + 8\ H_2SO_4 + 2\ KMnO_4 = 5\ Na_2SO_4 + K_2SO_4 + 2\ MnSO_4 + 8\ H_2O + 10\ CO_2$$

$$10\ KI + 16\ HCl + 2\ KMnO_4 = 10I + 12\ KCl + 2\ MnCl_2 + 8\ H_2O$$

$$10\ I + 10\ Na_2S_2O_3 = 5\ Na_2S_4O_6 + 10\ NaI$$

$$KIO_3 + 5\ KI + 6\ HCl = 6\ I + 6\ KCl + 3\ H_2O$$

$$KIO_3 + 5\ KI + 6\ HCl + 3\ H_2S = 3\ S + 6\ KCl + 6\ HI + 3\ H_2O$$

The ratios are, therefore:

$$5\ Na_2C_2O_4 : 2\ KMnO_4 = 10\ I : 5\ S$$

METHOD

Place 5 g. of the cast-iron sample in the flask (Fig. 2) and connect the latter as shown in the sketch. Place 10 cc. of the ammoniacal solution of cadmium chloride or zinc sulfate solution and 150 cc. of distilled water in the tumbler. Add 80 cc. of the dilute HCl (1:1) to

the flask through the thistle tube, heat the flask and its contents gently until the solution of the iron is complete, then boil the solution for ½ minute. The heat must be so adjusted that there is a rapid, steady evolution of gas. Disconnect the delivery tube leaving it in the solution and remove the tumbler. Add 5 cc. of starch solution, then 40 cc. of dilute HCl (1:1) and titrate *immediately* with the iodate solution to a permanent blue color.

NOTES

If cast-iron samples are not annealed and the theoretical titre is used, the results obtained by the evolution method will be low by as much as 0.015 per cent. Annealed samples behave more nearly normal, but there is enough uncertainty so that the evolution method should never be used when high accuracy or settlement of disputes are in question.

Samples are annealed as follows: Transfer 5.00 g. of the drillings to a 12.5-cm. filter paper, and wrap the sample securely in the paper so that at least three thicknesses of paper cover the iron. Place the packages in a 25-cc. porcelain crucible, cover the crucible tightly so that air cannot enter freely, and heat for 20 minutes at a bright red heat over a Meker burner or preferably in a muffle. The filter paper should be charred but not burned.

Direct sunlight should be avoided if cadmium solutions are used, otherwise low results are obtained. Cast irons of high titanium content do not yield all of their sulfur even after annealing.

DETERMINATION OF SILICON
BY THE
NITRO-SULFURIC ACID METHOD

SOLUTIONS REQUIRED

Nitro-Sulfuric Acid.—Mix 160 cc. of H_2SO_4 (sp. gr. 1.84), 180 cc. of HNO_3 (sp. gr. 1.42), and 660 cc. of water.

Dilute Hydrochloric Acid (5:95).—Mix 50 cc. of HCl (sp. gr. 1.19) and 950 cc. of distilled water.

METHOD

Add cautiously 100 cc. of the nitro-sulfuric acid to 2.336 g. of iron, in a platinum or porcelain dish of 300-cc. capacity, cover with a watch glass, heat until the iron is dissolved and evaporate until copious fumes of sulfuric acid are evolved. Cool, add 125 cc. of distilled water and 5 cc. of HCl (sp. gr. 1.19), heat with *frequent stirring* until all salts are dissolved and *immediately* filter on a 9-cm. paper. Wash the precipitate with cold dilute HCl (5:95) and hot water alternately to complete the removal of iron salts, and finally with hot water until free from acid. Transfer the filter to a platinum crucible, burn

the paper without inflaming, and finally ignite with the crucible covered over a blast lamp or in a muffle furnace at 1000° C., for at least 10 minutes, cool in a desiccator and weigh. Add sufficient dilute H_2SO_4 (1:1) to moisten the silica and then a small amount of HF. Evaporate to dryness, ignite and weigh. The difference in weights in milligrams divided by 50 equals the percentage of silicon.

A blank determination on all reagents used should be made and the results corrected accordingly.

DETERMINATION OF SILICON BY THE HYDROCHLORIC-SULFURIC ACID METHOD

To 2.336 g. of iron in a covered 600-cc. beaker or a 250-cc. casserole add 40 cc. of dilute HCl (1:1), heat gently until the solution is complete and then wash and remove the cover glass. Evaporate to dryness, but do not bake. If basic salts are formed by accidental baking, moisten the hot mass with 1 to 3 cc. of HCl (sp. gr. 1.19). Cool slightly, add 15 cc. of H_2SO_4 (sp. gr. 1.84), and scrape down any salts on the sides of the vessel. Evaporate to fumes of sulfuric acid, cool, add 150 cc. of water, and heat with frequent stirring until salts are in solution. Immediately filter on a 9-cm. paper and proceed as in the Determination of Silicon by the Nitro-Sulfuric Acid Method.[1]

NOTE.—This determination can be carried out in the HCl solution of the iron obtained in the Determination of Sulfur by the Evolution Method (Routine).[2]

DETERMINATION OF SILICON BY THE SULFURIC ACID METHOD (OPTIONAL)

SOLUTIONS REQUIRED

Dilute Hydrochloric Acid (5:95).—Mix 50 cc. of HCl (sp. gr. 1.19) and 950 cc. of distilled water.

METHOD

To 2.336 g. of iron in a 500-cc. beaker of low form add 60 cc. of distilled water, and then cautiously 15 cc. of H_2SO_4 (sp. gr. 1.84). Cover with a watch glass, heat until the iron is dissolved, remove the

[1] See p. 468. [2] See p. 466.

cover, and evaporate until copious fumes of sulfuric acid are evolved. Cool, add 100 cc. of distilled water and heat with frequent stirring until the salts are in solution. Immediately filter on a 9-cm. paper and proceed as in the Determination of Silicon by the Nitro-Sulfuric Acid Method.[1]

DETERMINATION OF SMALL AMOUNTS OF CHROMIUM

SOLUTIONS REQUIRED

Dilute Sulfuric Acid (1:9).—Slowly stir 100 cc. of H_2SO_4 (sp. gr. 1.84) into cool water, cool, and then dilute to 1000 cc. It is important that this acid be of the indicated strength.

Sodium Bicarbonate Solution.—Dissolve 80 g. of $NaHCO_3$ in water and dilute to 1000 cc.

Dilute Sulfuric Acid (1:1).—Slowly stir 500 cc. of H_2SO_4 (sp. gr. 1.84) into 500 cc. of water.

Dilute Nitric Acid (sp. gr. approximately 1.20).—Mix 380 cc. of HNO_3 (sp. gr. 1.42) and 620 cc. of distilled water.

Silver Nitrate Solution (0.133-per-cent).—Dissolve 1.33 g. of $AgNO_3$ in 1000 cc. of water.

Ammonium Persulfate Solution (10-per-cent).—Make up as needed by dissolving 10 g. of the salt in 100 cc. of water. The salt should be at least 95-per-cent pure and can be tested as follows: Dissolve 0.3 g. of the salt, accurately weighed, in 25 cc. of a 10-per-cent solution of potassium iodide and add 10 cc. of dilute sulfuric acid (1:9). Let stand for $\frac{1}{2}$ hour and titrate the liberated iodine with a 0.1 *N* solution of sodium thiosulfate. One cubic centimeter 0.1 *N* $Na_2S_2O_3$ equals 0.01141 g. of $(NH_4)_2S_2O_8$. Or, the salt can be tested by treating 0.3 g. of the salt with 30 cc. of 0.1 *N* $FeSO_4$ solution and then with 200 cc. of hot water in a non-oxidizing atmosphere. After the salt has dissolved, cool and determine the excess of $FeSO_4$ by titration with 0.1 *N* $KMnO_4$ solution.

Sodium Chloride Solution (5-per-cent).—Dissolve 5 g. of NaCl in 100 cc. of water.

Standard Ferrous Sulfate Solution (0.03 N.).—See the Determination of Manganese by the Bismuthate Method.[2]

Standard Potassium Permanganate Solution.—See the Determination of Manganese by the Bismuthate Method.[2]

Sodium Hydroxide Solution (5-per-cent).—Dissolve 50 g. of stick NaOH in 1000 cc. of water.

[1] See p. 468. [2] See p. 457.

Standard Potassium Chromate.—Dissolve 0.2828 g. of c. p. $K_2Cr_2O_7$ in 1000 cc. of water. One cubic centimeter of this solution contains 0.1 mg. of chromium. In the colorimetric comparison the solution is added to a NaOH solution of the same strength as the solution which is to be tested.

METHOD

(*a*) *Titration Method* (*Referee Method*).

Treat 10 g. of the sample, contained in a 500-cc. Erlenmeyer flask, with 110 cc. of dilute H_2SO_4 (exactly 1:9). Cover, heat to boiling, and as soon as the action is complete dilute to 200 cc. with boiling water (See Note). Immediately add 50 cc. of sodium bicarbonate solution slowly and with stirring from a pipette, and then continue the addition from a burette until a permanent precipitate appears (10 to 30 cc. depending on the composition of the iron) and then add 4 cc. more. Boil for one minute, let settle, filter on a rapid filter and quickly wash the flask and precipitate two or three times with hot water. If the proper portions of iron and H_2SO_4 were taken in the beginning and the precipitation is properly performed, there will be no more precipitate than can be conveniently handled on an 11-cm. paper. The filtrate will become cloudy in the funnel stem and in the receiving vessel on account of oxidation and hydrolysis. Ignite the paper and precipitate in an iron or nickel crucible (free from chromium), mix the ash with ten or twelve times its volume of sodium peroxide (free from chromium) and heat gently until the contents are fused. Dissolve the cooled melt by immersing it in 100 cc. of cold water, remove the crucible and destroy any remaining peroxide by heating for at least ½ hour on the steam bath. Filter through paper or an asbestos pad, wash with hot water and discard the residue.

If some iron passes into the filtrate, it will not interfere with the subsequent titration of chromium. Neutralize the filtrate with H_2SO_4 (1:1), using litmus paper as indicator, and add 20 cc. in excess. Add 5 cc. of HNO_3 (sp. gr. 1.20), 10 cc. of $AgNO_3$ solution and 20 cc. of freshly prepared ammonium persulfate solution (10-per-cent). *Boil* for 10 minutes. If small amounts of permanganic acid are now indicated, add 5 cc. of NaCl solution (5-per-cent) and continue the boiling for 5 minutes after the pink color has been destroyed. If no permanganate acid is indicated, as is usually the case, the boiling with NaCl can be omitted. Cool the solution, dilute to 300 cc. and titrate for chromium by adding a small measured excess of the stand-

ard ferrous sulfate solution and then titrating back with an approximately 0.03 *N* standard potassium permanganate solution. The titration should be corrected by a "blank" run carried through the various steps of the method, not omitting the fusion which tests the crucible.

(*b*) *Colorimetric Method* (*Routine*).

A reasonably correct determination of small amounts of chromium requires such care that a rapid routine method is not possible. The Titration Method (Referee Method), above, can be shortened somewhat for less accurate work as follows:

When the hydrogen peroxide has been destroyed, filter the NaOH solution through an asbestos pad, preferably on a Büchner funnel and wash with a cold 5-per-cent solution of NaOH. Dilute to a measured volume (preferably 100 cc.) and compare the color with a standard solution of $K_2Cr_2O_7$. In this method peroxide need not be destroyed, but the solution is heated to give better separation of iron which occasionally goes through the filter and gives a false color.

In colorimetric work asbestos should be used as the filtering medium as coloring matter may be extracted from filter paper by strongly alkaline solutions.

Vanadium is quantitatively precipitated by sodium bicarbonate in this method, but it does not interfere in the determination of chromium in either volumetric or colorimetric methods.

NOTE.—As soon as attack is complete, the solution can be rapidly filtered by suction, the paper and contents washed with hot water and burned with the bicarbonate precipitate. This aids a beginner to determine the bicarbonate end point.

DETERMINATION OF NICKEL BY THE DIMETHYLGLYOXIME METHOD

SOLUTIONS REQUIRED

Dilute Hydrochloric Acid (*1:1*).—Mix 500 cc. of HCl (sp. gr. 1.19) and 500 cc. of water.

Dilute Hydrochloric Acid (*1:20*).—Mix 50 cc. of HCl (sp. gr. 1.19) and 1000 cc. of water.

Dimethylglyoxime Solution (*1-per-cent*).—Dissolve 20 g. of dimethylglyoxime in 1300 cc. of NH_4OH (sp. gr. 0.90) and dilute to 2000 cc. Ten cubic centimeters of this solution allow sufficient excess to completely precipitate 0.015 g. of nickel.

METHOD

Dissolve 5 g. of the iron in 40 cc. of dilute HCl (1:1), add about 10 cc. of HNO_3 (sp. gr. 1.42) to oxidize the iron, and evaporate to dryness on the steam bath. Drench the dried mass with 10 cc. of HCl (sp. gr. 1.19) and then dilute with 100 cc. of hot water. Filter, wash with dilute HCl (1:20) and evaporate the filtrate to a syrupy consistency. Take up in 15 cc. of HCl (1:1) and transfer to a 150 or 250-cc. separatory funnel, rinsing the beaker several times with small portions of dilute HCl (1:1). Cool, add 50 cc. of ether, shake for 1 to 2 minutes in a stream of cold water, let settle for one minute, and then draw off the lower clear solution. Add 10 cc. of cold dilute HCl (1:1) to the solution in the separatory funnel, shake thoroughly, allow to settle for one minute, and again draw off the clear solution into the same beaker as was used for the first. Gently heat the solution in the beaker to expel the ether, add 0.2 g. of potassium chlorate, boil until the chlorate is decomposed, dilute to 100 cc. and add 3 g. of tartaric acid. Make the solution alkaline with ammonia and filter. If a precipitate of iron is present insufficient tartaric acid was added. In this case the precipitate must be dissolved in HCl, the whole solution acidified, and treated with more tartaric acid. If no precipitate appears, render the solution slightly acid with HCl, dilute to 200 cc. and add 20 cc. of dimethylglyoxime solution. Heat to boiling, make slightly ammoniacal, and let stand on the steam bath for one hour. Filter on a weighed Gooch Pyrex-Alundum, or fritted-glass crucible, wash with hot water and dry for one hour at 110 to 120° C. Weigh as nickel-dimethylglyoxime and multiply the weight by 0.2031 to obtain the weight of nickel.

NOTE.—In routine analyses, the dimethylglyoxime precipitate can be caught on paper and ignited to NiO or decomposed and titrated with cyanide. In the former case, care must be taken to prevent sublimation of the undecomposed salt. This can be accomplished by enclosing the wet paper and precipitate in one or two wet ashless papers and slowly igniting so that the papers char before taking fire. In this way the compound is decomposed and ignition can then proceed at full red heat. In the latter case proceed as follows: dissolve the nickel-dimethylglyoxime in HNO_3, oxidize with ammonium persulfate or potassium chlorate and boil for 5 minutes. Cool, neutralize with NaOH and add 5 cc. in excess. Rosolic acid is a convenient indicator. Dilute to 200 cc., cool thoroughly, add 2 cc. of a 10-per-cent solution of KI and then from a burette 1 cc. of standard $AgNO_3$ solution (5.7903 g. per liter). Titrate with a standard solution of potassium cyanide (4.5 g. KCN per liter) until the AgI is dissolved. Finish the titration by adding $AgNO_3$ to a reappearance of the opalescence. With exactly agreeing $AgNO_3$ and KCN solutions, each cubic centimeter excess of standard cyanide solution over the $AgNO_3$ solution will equal 0.1 per cent nickel on a 1-g. sample.

DETERMINATION OF COPPER

SOLUTIONS REQUIRED

Dilute Sulfuric Acid (1:5).—Slowly stir 200 cc. of H_2SO_4 (sp. gr. 1.84) into 1000 cc. of distilled water.

Dilute Sulfuric Acid (2:98).—Mix 20 cc. of H_2SO_4 (sp. gr. 1.84) and 980 cc. of distilled water.

Acidulated Hydrogen Sulfide Water.—Saturate 500 cc. of dilute sulfuric acid (2:98) with hydrogen sulfide.

Sodium Hydroxide (5-per-cent).—Dissolve 50 g. of stick NaOH in 1000 cc. of distilled water and filter through asbestos if necessary.

Sodium Thiosulfate (50-per-cent).—Dissolve 100 g. of $Na_2S_2O_3 \cdot 5H_2O$ in 100 cc. of distilled water and filter if necessary.

Dilute Nitric Acid (1:1).—Mix 500 cc. of HNO_3 (sp. gr. 1.42) and 500 cc. of distilled water.

METHOD

(*a*) *Precipitation by Hydrogen Sulfide (Referee Method).*

Dissolve 10.0 g. of iron in 100 cc. of dilute H_2SO_4 (1:5), and when solution is complete evaporate to fumes of sulfuric acid, cool, dilute to 100 cc. and filter. Wash the residue with hot water and dilute the filtrate to 500 cc. with water. Heat to boiling and saturate with H_2S. Digest for 1 to 2 hours, filter on paper or paper pulp and wash with acidulated hydrogen sulfide water. Ignite the precipitate and paper in a porcelain crucible and fuse with a small amount of alkali pyro-sulfate. Dissolve the cooled melt in 50 cc. of dilute H_2SO_4 (2:98), transfer to a 200-cc. beaker, dilute to 100 cc. and add NaOH (5-per-cent) solution in slight excess. Boil, digest, and filter, in order to separate such elements as vanadium, tungsten and molybdenum. Dissolve the precipitate in hot dilute HNO_3 (1:1), add 5 cc. of H_2SO_4 (sp. gr. 1.84), evaporate to the appearance of fumes of sulfuric acid, cool, dilute to 40 cc., filter and add sufficient NH_4OH (sp. gr. 0.90) to reduce the acidity to approximately 2 cc. of H_2SO_4 (sp. gr. 1.84) per 100 cc. of solution. Heat the acid solution to boiling and saturate with H_2S. Digest a while, filter, wash thoroughly with acidulated H_2S water, and proceed according to method 1 or 2 below.

(*b*) *Precipitation by Thiosulfate.*

Transfer 5 g. of the sample to a 600-cc. beaker, add 100 cc. of H_2SO_4 (1:5), and heat until the sample is dissolved. Dilute to 300 cc.

heat to boiling, add 15 cc. of thiosulfate solution (50-per-cent) and continue the boiling for 5 minutes or until the precipitate of copper sulfide has coagulated. Collect the precipitate upon an 11-cm. paper and wash *slightly* with dilute H_2SO_4 (2:98). Ignite the residue and paper in a porcelain crucible and fuse with alkali pyrosulfate. Dissolve the cooled melt in the crucible in 1 to 2 cc. of HCl (sp. gr. 1.19) and a few cubic centimeters of water, transfer to a 200-cc. beaker, dilute to 100 cc. and add NaOH (5-per-cent) solution in slight excess. Boil, digest and filter in order to separate such elements as vanadium, tungsten and molybdenum. Dissolve the precipitate in hot dilute HNO_3 (1:1), carefully add 20 cc. of H_2SO_4 (sp. gr. 1.84), evaporate to the appearance of fumes of H_2SO_4, cool, dilute, and filter. Dilute the solution to a volume of 300 cc. and precipitate the copper with thiosulfate as above. Filter, wash with dilute H_2SO_4 (2:98) until sodium salts have been removed and proceed according to method 1 or 2 below.

(1) *Electrolytic Method.*—Dissolve the sulfides obtained as above in hot dilute HNO_3 (1:1), and electrolyze after the addition of H_2SO_4 according to usual procedures.

(2) *Gravimetric Method.*—Ignite the sulfides obtained as above and weigh as copper oxide. As this compound is somewhat hygroscopic, care must be observed to prevent the absorption of moisture. It is difficult to convert large amounts of CuS to CuO by ignition and if the percentage of copper is in excess of 0.2, the electrolytic method should be used or the size of sample reduced.

DETERMINATION OF COPPER

(ROUTINE METHOD)

SOLUTIONS REQUIRED

Potassium Ferrocyanide.—Dissolve 10 g. of potassium ferrocyanide in 100 cc. of distilled water.

Standard Copper Nitrate.—Dissolve 2 g. of purest electrolytic copper in 20 cc. of HNO_3 (1:1), and dilute to 1000 cc. with distilled water. Each cubic centimeter is equivalent to 0.02 per cent of copper on the basis of a 10-g. sample.

METHOD

Proceed as in (*a*) Precipitation by Hydrogen Sulfide or (*b*) Precipitation by Thiosulfate, under Determination of Copper[1] until the alkali pyrosulfate fusion has been made. Extract the cooled melt

[1] See p. 474.

with hot water, filter, and complete the determination colorimetrically as follows:

Evaporate the filtrate to about 25 cc., filter into a 100-cc. Nessler tube, wash with hot water, add 5 cc. of NH_4OH (sp. gr. 0.90) and dilute to 50 cc.

(*a*) *If the solution is a strong blue.*—

To another 100-cc. Nessler tube add 50 cc. of distilled water, 5 cc. of NH_4OH (sp. gr. 0.90) and from a burette the standard copper nitrate solution until the blue colors match.

(*b*) *If the solution is a faint blue.*—

To the filtrate in a Nessler tube add dilute H_2SO_4 (1:5) to faint acidity and then a few drops of the potassium ferrocyanide solution. To another 100-cc. Nessler tube add 50 cc. of distilled water, a few drops of the potassium ferrocyanide solution, and from a burette the standard copper nitrate solution until the reddish brown colors match.

DETERMINATION OF TITANIUM BY THE COLORIMETRIC METHOD

SOLUTIONS REQUIRED

Dilute Hydrochloric Acid (*1:2*).—Mix 500 cc. of HCl (sp. gr. 1.19) with 1000 cc. of water.

Dilute Sulfuric Acid (*1:9*).—Carefully stir 100 cc. of H_2SO_4 (sp. gr. 1.84) into 900 cc. of water.

Standard Titanium Solution.—Transfer 3 g. of potassium titanium fluoride (K_2TiF_6), which has been twice recrystallized from hot water, to a platinum dish, add 100 cc. of H_2SO_4 (sp. gr. 1.84) and evaporate three times to fumes of the acid, with intervening washing down of the sides of the vessel. Cool and pour the solution rapidly and with stirring into 900 cc. of water. Cool to room temperature, and standardize the solution by taking 100-cc. portions, precipitating with ammonia in boiling solution, filtering, igniting and weighing as TiO_2.

Ferric Sulfate Solution.—Dissolve 10 g. of ingot iron or plain carbon steel which is free from titanium in HNO_3, add 20 cc. of H_2SO_4 (sp. gr. 1.84), evaporate to fumes of sulfuric acid, cool and dilute to 100 cc.

METHOD

Dissolve 5.00 g. of the sample in 100 cc. of HCl (1:2). When all action has ceased, filter, wash the insoluble matter with water, dry and ignite in a platinum crucible under good oxidizing conditions. Treat with 1 to 2 cc. of HF and 1 cc. of dilute H_2SO_4 (1:1) to eliminate silica, and evaporate to dryness. Fuse the residue with sodium carbonate, dissolve the fusion in water, digest for 15 minutes, filter and wash with water. Ignite the residue in platinum, fuse with a small quantity of alkali pyrosulfate, cool, and take up in dilute H_2SO_4 (1:9). Compare the amount of titanium in this solution with a standard titanium solution as follows: Treat the proper amount of a standard titanium solution with the same quantity of alkali pyrosulfate as was used in the above fusion and add sufficient ferric sulfate solution to give the same tint as the sample when both are at the same dilution. Add 2 cc. of 3-per-cent hydrogen peroxide to the solution and standard respectively and compare in a colorimeter.

DETERMINATION OF ARSENIC

(UMPIRE METHOD)

(AS As_2S_3 OR BY TITRATION WITH KSCN)

Dissolve the sample (10.0 g.) in 200 cc. of dilute HNO_3 (1:3). Retard action by cooling if it grows violent. After solution is complete, cool, add 50 cc. of concentrated H_2SO_4 and evaporate until fumes of sulfuric acid begin to appear. Remove from the hot plate, cool, wash down the sides of the beaker, and fume again. (It is better to fume twice moderately than to fume once very strongly on account of the possibility of volatilizing arsenic at the higher temperature). Cool, carefully add 50 cc. of water and again cool to room temperature.

Transfer the solution by means of 150 to 175 cc. of concentrated HCl to a distillation flask fitted with a two-holed stopper, preferably of glass, carrying a separatory funnel and an outlet tube. The latter should be provided with a hole on the side about 1 cm. from the end within the distillation flask. This allows for circulation in the outlet tube and prevents small particles of the material in the flask from passing over into the distillate. Add 20 g. of cuprous chloride, stopper and connect the outlet tube with a vertical condenser having its lower end dipping into a beaker containing 150 cc. of distilled water and immersed in ice-water. Distill until 100 cc. of distillate have passed over.

After the distillation is done, add 15 cc. of strong NH_4OH (sp. gr. 0.90), to the distillate in order to neutralize some of the acid and pass

a rapid stream of H_2S through the solution until saturated. Allow to stand at least one hour, preferably overnight.

(*a*) *To weigh as* As_2S_3.—

Filter on a weighed Gooch crucible, wash with alcohol, then with carbon disulfide, then with alcohol, and dry at 100 to 105° C. Weigh as As_2S_3 and multiply by the factor 0.6092 to obtain the weight of arsenic.

(*b*) *To Titrate with KSCN*.—

Titration with KSCN does away with uncertainty concerning the purity of the arsenic sulfide and is done as follows:

Filter through asbestos or paper and wash the precipitate moderately with dilute H_2SO_4 (1:99) that has been saturated with H_2S. Dissolve the washed sulfide in 2 to 3 cc. of strong NH_4OH or the same volume of a 10-per-cent solution of NaOH. Wash the pad or paper with water, evaporate nearly to dryness, add 10 cc. of concentrated HNO_3 and again evaporate nearly to dryness. Take up with 50 cc. of water, add a few drops of phenolphthalein and then a 10-per-cent solution of NaOH drop-by-drop until the solution is decidedly alkaline. Now add dilute acetic acid (1:1) drop-by-drop until the solution just turns colorless, and precipitate the arsenic as silver arsenate by the addition of 10 cc. of $AgNO_3$ solution (34 g. per liter). Heat just to boiling to coagulate the precipitate, cool, filter on an asbestos pad, and wash with cold water.

Dissolve the silver arsenate in dilute HNO_3 (1:1) and titrate the silver in the solution with 0.01 *N* potassium or ammonium sulfocyanate, using ferric alum (free from chlorides) as the indicator. The sulfocyanate solution may be standardized against either pure silver or pure silver nitrate and its arsenic titre calculated from the ratio 3 Ag:1 As.

NOTES

A blank determination should be carried through all steps of the determination.

Distillation should be carried out so that no copper from the cuprous chloride is carried over into the distillate.

In routine analyses, the HCl distillate may be nearly neutralized with NaOH, the still acid solution treated with an excess of sodium bicarbonate and the arsenic determined by titration with a standard 0.01 *N* solution of iodine in the presence of starch as indicator. The iodine solution is preferably standardized against a standard iron carried through the method.

STANDARD SPECIFICATIONS
FOR
TUNGSTEN POWDER[1]

Serial Designation: A 97 – 27

These specifications are issued under the fixed designation A 97; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1925; ADOPTED, 1927.

1. These specifications cover tungsten powder in one grade only. **Scope.**

2. The tungsten powder shall be thoroughly mixed and packed in sound containers preferably metallic or metallic lined and sufficiently strong to prevent loss in transportation. **Basis of Purchase.**

3. The material shall conform to the following requirements as to chemical composition: **Chemical Requirements.**

Metallic Tungsten, minimum	95.00 per cent
Carbon, maximum	0.50 "
Sulfur, maximum	0.05 "
Phosphorus, maximum	0.05 "
Oxygen, maximum	1.00 "
Silicon, maximum	0.75 "
Tin, maximum	0.03 "
Copper, maximum	0.03 "
Arsenic, maximum	0.03 "
Bismuth, maximum	0.03 "
Antimony, maximum	0.03 "

4. When agreed upon by the purchaser and seller the sampling shall be carried out in accordance with the Standard Methods of Sampling Ferro-Alloys (Serial Designation: A 103) of the American Society for Testing Materials.[2] **Sampling.**

5. When agreed upon by the purchaser and seller the chemical analysis shall be carried out in accordance with the Standard Methods of Chemical Analysis of Ferro-Alloys (Serial Designation: A 104) of the American Society for Testing Materials.[3] **Methods of Chemical Analysis.**

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-9 on Ferro-Alloys.

[2] See p. 485.

[3] See p. 489.

STANDARD SPECIFICATIONS
FOR
SPIEGELEISEN[1]

Serial Designation: A 98 – 27

These specifications are issued under the fixed designation A 98; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1925; ADOPTED, 1927.

Scope.

1. These specifications cover spiegeleisen in two grades, as follows:

Grade A; and
Grade B.

Basis of Purchase.

2. The spiegeleisen shall be furnished in pigs or lumps and each shipment shall be uniform as to the grade specified.

Chemical Requirements.

3. The material shall conform to the following requirements as to chemical composition:

	MANGANESE, PER CENT	CARBON, MAX., PER CENT	PHOSPHORUS, MAX., PER CENT	SULFUR, MAX., PER CENT	SILICON, MAX., PER CENT
Grade A.....	19 to 21	6.50	0.15	0.04	as specified
Grade B.....	16 to 19	6.50	0.25	0.05	as specified

Sampling.

4. When agreed upon by the purchaser and seller the sampling shall be carried out in accordance with the Standard Methods of Sampling Ferro-Alloys (Serial Designation: A 103) of the American Society for Testing Materials.[2]

Methods of Chemical Analysis.

5. When agreed upon by the purchaser and seller the chemical analysis shall be carried out in accordance with the Standard Methods of Chemical Analysis of Ferro-Alloys (Serial Designation: A 104) of the American Society for Testing Materials.[3]

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-9 on Ferro-Alloys.

[2] See p. 485.

[3] See p. 489.

STANDARD SPECIFICATIONS
FOR
FERRO-MANGANESE[1]

Serial Designation: A 99 – 27

These specifications are issued under the fixed designation A 99; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1925; ADOPTED, 1927.

Scope.

1. These specifications cover ferro-manganese in one grade only.

Basis of Purchase.

2. Ferro-manganese shall be furnished in pigs, lumps, crushed or screened to size, as specified.

Chemical Requirements.

3. The material shall conform to the following requirements as to chemical composition:

Manganese, minimum	78.00 per cent
Phosphorus, maximum	0.35 "
Carbon, maximum	7.5 "
Silicon, maximum	1.00 "
Sulfur, maximum	0.050 "

Sampling.

4. When agreed upon by the purchaser and seller the sampling shall be carried out in accordance with the Standard Methods of Sampling Ferro-Alloys (Serial Designation: A 103) of the American Society for Testing Materials.[2]

Methods of Chemical Analysis.

5. When agreed upon by the purchaser and seller the chemical analysis shall be carried out in accordance with the Standard Methods of Chemical Analysis of Ferro-Alloys (Serial Designation: A 104) of the American Society for Testing Materials.[3]

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-9 on Ferro-Alloys.

[2] See p. 485. [3] See p. 489.

STANDARD SPECIFICATIONS
FOR
FERRO-SILICON[1]

Serial Designation: A 100 – 27

These specifications are issued under the fixed designation A 100; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1925; ADOPTED, 1927.

Scope.

1. These specifications cover ferro-silicon in three grades, as follows:

Grade A;
Grade B; and
Grade C.

Basis of Purchase.

2. (*a*) The ferro-silicon shall be furnished in lumps, or crushed or screened to size, as specified.

(*b*) When furnished in lump or granulated form the ferro-silicon shall be free from excessive disintegration.

Chemical Requirements.

3. The material shall conform to the following requirements as to chemical composition:

	GRADE A	GRADE B	GRADE C
Silicon, per cent.....	47.00 to 53.00	72.00 to 78.00	85.00 to 95.00

4. An analysis of each shipment of ferro-silicon shall be furnished the purchaser, showing the percentage of silicon.

Sampling.

5. When agreed upon by the purchaser and seller the sampling shall be carried out in accordance with the Standard Methods of Sampling Ferro-Alloys (Serial Designation: A 103) of the American Society for Testing Materials.[2]

Methods of Chemical Analysis.

6. When agreed upon by the purchaser and seller the chemical analysis shall be carried out in accordance with the Standard Methods of Chemical Analysis of Ferro-Alloys (Serial Designation: A 104) of the American Society for Testing Materials.[3]

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-9 on Ferro-Alloys.

[2] See p. 485. [3] See p. 489.

STANDARD SPECIFICATIONS
FOR
FERRO-CHROMIUM[1]

Serial Designation: A 101 - 27

These specifications are issued under the fixed designation A 101; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1925; ADOPTED, 1927.

Scope.

1. These specifications cover ferro-chromium in four grades, as follows:

High Carbon, Grade A;
Low Carbon, Grades B, C, and D.

Basis of Purchase.

2. (*a*) *Ferro-Chromium, High-Carbon.*—This material shall be furnished to size as specified.

(*b*) *Ferro-Chromium, Low Carbon.*—This material shall be crushed to the specified size and mixed before packing, so that the quality in each package is uniform with the lot.

Chemical Requirements.

3. The material shall conform to the following requirements as to chemical composition:

	High Carbon	Low Carbon		
	Grade A	Grade B	Grade C	Grade D
Chromium, per cent	60.00 to 75.00	60.00 to 75.00	60.00 to 75.00	60.00 to 75.00
Carbon, per cent	4.00 to 8.00	1.50 to 2.00	1.00 to 1.50	under 1.00
Silicon, per cent	as specified	as specified	as specified	as specified[a]

[a] Grade D material may be obtained with various maxima carbon contents down to 0.10 per cent of carbon.

Sampling.

4. When agreed upon by the purchaser and seller the sampling shall be carried out in accordance with the Standard Methods of Sampling Ferro-Alloys (Serial Designation: A 103) of the American Society for Testing Materials.[2]

Methods of Chemical Analysis.

5. When agreed upon by the purchaser and seller the chemical analysis shall be carried out in accordance with the Standard Methods of Chemical Analysis of Ferro-Alloys (Serial Designation: A 104) of the American Society for Testing Materials.[3]

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-9 on Ferro-Alloys.

[2] See p. 485. [3] See p. 489.

STANDARD SPECIFICATIONS
FOR
FERRO-VANADIUM[1]

Serial Designation: A 102 – 27

These specifications are issued under the fixed designation A 102; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1925; ADOPTED, 1927.

Scope.

1. These specifications cover ferro-vanadium in four grades, as follows:

Grade A;
Grade B;
Grade C; and
Grade D.

Basis of Purchase.

2. The material furnished under this specification shall be crushed to the specified size, and mixed before packing, so that the quality in each package is uniform with the lot. The material shall be packed in sound containers, sufficiently strong to prevent loss in transportation.

Chemical Requirements.

3. The material shall conform to the following requirements as to chemical composition:

	Grade A	Grade B	Grade C	Grade D
Vanadium, per cent	30.00 to 40.00	30.00 to 40.00	35.00 to 45.00	35.00 to 45.00
Carbon, per cent	3.00 to 6.00	1.5 to 3.00	not over 1.5	not over 0.75
Silicon, per cent	8.00 to 15.00	5.00 to 8.00	not over 2.00	not over 2.00
Phosphorus, per cent	not over 0.250	not over 0.250	not over 0.150	not over 0.100
Sulfur, per cent	not over 0.300	not over 0.300	not over 0.200	not over 0.100
Aluminum, per cent	not over 2.00	not over 2.00	not over 2.00	not over 1.00

Sampling.

4. When agreed upon by the purchaser and seller the sampling shall be carried out in accordance with the Standard Methods of Sampling Ferro-Alloys (Serial Designation: A 103) of the American Society for Testing Materials.[2]

Methods of Chemical Analysis.

5. When agreed upon by the purchaser and seller the chemical analysis shall be carried out in accordance with the Standard Methods of Chemical Analysis of Ferro-Alloys (Serial Designation: A 104) of the American Society for Testing Materials.[3]

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-9 on Ferro-Alloys.

[2] See p. 485.] [3] See p. 489.

STANDARD METHODS
OF
SAMPLING FERRO-ALLOYS[1]

Serial Designation: A 103 – 27

These methods are issued under the fixed designation A 103; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1925; ADOPTED, 1927.

The procedures recommended in these methods are considerably more elaborate than those in general use by the principal consumers of ferro-alloys in this country. However, the methods have been designed as standard procedure for use in important cases where large sums are often involved and they accordingly should represent the most approved modern practice.

FERRO-SILICON, HIGH-CARBON FERRO-MANGANESE AND SILICO-MANGANESE

These alloys are usually shipped in bulk in carloads and should be sampled while being loaded or unloaded. At these times the sampler can make the fairest estimate of the ratio of lump to fine material and should secure proportionate amounts of each. Frequently the percentage of fines is negligible.

While the shipment is being loaded or unloaded, samples aggregating 150 lb. or more shall be gathered from all parts of the car with due regard to the estimated ratio of lump to fine material. In breaking lumps or pigs, fragments representing the full cross-section should be secured, a heavy hammer or sledge being employed.

The gross sample thus obtained shall be crushed to pea size in a heavy crusher provided with smooth plates of manganese steel. The crushed product shall be repeatedly mixed and halved with a Jones divider until about 5 lb. remain. If a Jones divider is not available, the sample may be reduced by "quartering," but use of the divider is preferred. The sample shall be further reduced to approximately a size to pass a No. 10 sieve[2] in laboratory rolls and again cut down by a Jones divider or by "quartering" to about 300 g. This sample shall then be divided in the same way into four portions of approximately 75 g. each and three of these shall be reserved. The fourth portion shall be pulverized until all has been passed through a No. 80 or No. 100 sieve.[2] A steel mortar with a close-fitting pestle, both of hardened alloy steel, shall be used for this reduction. Rejection of

[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee A-9 on Ferro-Alloys.

[2] For detailed specifications for these sieves, see Standard Specifications for Sieves for Testing Purposes (Serial Designation: E 11) of the American Society for Testing Materials, see p. 789.

any part of the sample because of failure to pass the screen is almost sure to produce error. The sample shall be thoroughly mixed, dried for one hour at 105 to 110° C. It is then ready for analysis. If necessary, one-half rather than one-fourth of the 10-mesh sample shall be pulverized to pass a No. 80 or No. 100 sieve and the resulting sample divided for distribution to the interested parties.

HIGH-CARBON FERRO-CHROMIUM, CHROMIUM METAL, LOW-CARBON FERRO-MANGANESE AND MANGANESE METAL

These alloys are usually shipped in stout kegs or barrels. Most of these products are relatively costly, and accuracy in sampling is extremely important even when the tonnage involved is small.

If the shipment is believed to be fairly uniform in composition and contains only a small percentage of fines, a satisfactory sample can be obtained by removing the ends or cutting the sides of the packages and taking from each at least 0.5 per cent of the contents. Thus at least 2½ lb. would be taken from a package containing 500 lb. If the product has been crushed to a small size, for example ¼ to ¾ in., the sample can be taken with a shovel or scoop. If the material is in larger pieces, as is usual with high-carbon ferro-chromium, the sample shall be taken by breaking fragments from a number of lumps until the requisite weight has been obtained as already described for the sampling of lumps of ferro-silicon. The gross sample shall be obtained by combining the samples taken from the individual packages and crushed and worked down in the manner described for the preceding group of alloys.

The relatively simple procedure of the preceding paragraph is justified only when experience has shown that the product being sampled contains no more than a small percentage of "fines" and is relatively uniform in composition. The "fines" usually differ somewhat in composition from the lumps and always work toward the bottom of the container while in transit. Products like tungsten powder or pulverized ferro-silicon (80 to 85 per cent Si) are also liable to segregate while in transit and should be sampled in a manner to avoid error due to the accumulation of a heavy constituent in the bottom of the container. The term "relatively uniform in composition" applies to a shipment or a sub-lot of a shipment in which the composition of any package is approximately the same as that of any other. Frequently a shipment comprises two or more lots, each uniform in composition within itself, but differing in this respect from the other lots. In these cases, each lot shall be sampled separately. If the product is rather variable in composition or if it contains a considerable proportion of fines, all of the packages comprising the shipment or lot shall be emptied and from each shall be taken a sample

amounting to at least 0.5 per cent of the contents. The percentage of fine and lump alloy in each barrel shall be estimated and the sampling conducted accordingly. In sampling a small lot which varies widely in composition within itself, it is good practice to empty all of the packages, combine the entire contents and mix the lot thoroughly. The pile shall then be "quartered" repeatedly until a sample is obtained approximating 5 per cent of the weight of the entire lot. The gross sample obtained by combining samples from the individual barrels or by "quartering" the entire shipment shall be crushed and worked down in the manner described for the group containing ferro-silicon.

LOW-CARBON FERRO-CHROMIUM

Low-carbon ferro-chromium is ordinarily shipped in stout kegs. The alloy usually contains about 70 per cent of chromium together with maximum contents of carbon ranging from 0.1 to 2 per cent. The combination of hardness and toughness characteristic of this product, particularly of the lower carbon grades, makes it the most difficult by far of any of the ferro-alloys to sample properly. In view of the great importance of the accurate determination of the carbon content—especially of the alloy containing a maximum of 0.1 per cent of carbon—the utmost care must be taken to avoid contamination of the sample with fragments of steel from the tools. Fortunately low-carbon ferro-chromium is usually uniform in composition and free from "fines."

If the alloy is known to be reasonably uniform in composition, 10 lumps shall be drawn from each package in the shipment or sub-lot. This can be accomplished by removing the head or cutting the side of the keg. If the composition is variable, each package of the shipment or sub-lot shall be emptied and about 20 lumps taken at random. The number of lumps should be varied according to the net weight of the package and the average size of the lumps found in it. One fragment about $\frac{1}{8}$ in. in diameter shall be broken from each lump of the gross sample, using a heavy hammer and a plate of hardened alloy steel. As nearly as possible each fragment should offer a cross-section of the lump from which it was taken. The resulting sample shall be crushed to approximately a size to pass a No. 10 sieve by means of a mortar and pestle of hardened alloy steel. This material shall be cut down with a Jones divider or "quartered" until 30 or 40 g. remain. This quantity shall then be pulverized to pass a No. 40 sieve by means of the mortar and pestle. Especially in pulverizing the grades relatively low in carbon, an air hammer is almost indispensable. The material passing a No. 40 sieve shall be split into two

or four parts according to the requirements, by means of a Jones divider or by "quartering." The following procedure is recommended for those cases in which prolonged crushing has resulted in a powder which passes entirely through a No. 20 sieve but which passes a No. 40 sieve in part only. The entire sample shall be passed through a No. 20 sieve and then divided into fractions finer and coarser than No. 40. The fractions shall be weighed and preserved in separate packages upon which are recorded the percentages by weight of the two sizes. The fractions may be analyzed separately or a composite sample may be prepared for the determination of each element, by weighing and subsequently combining the proper proportions of the coarse and fine material.

REQUIREMENTS FOR MORTAR AND PESTLE

In the analysis of ferro-alloys, errors arising from contamination of the sample by iron from the sampling appliances are both serious and common. A rapid and accurate method for the determination of unalloyed metallic iron in ferro-chromium and in ferro-silicon is known, and by this means such contamination has been detected and measured. Contamination has often been due to iron from the mortar and pestle but can be avoided by the proper selection and treatment of the steel from which they are made. These tools are essential to the accurate sampling of ferro-alloys—especially low-carbon ferro-chromium —and when made in accordance with the following requirements are suitable for this purpose.

Chromium-nickel steel containing approximately 1.5 per cent Cr, 3 per cent Ni, and 0.35 per cent C is recommended for both tools. For the mortar a cylinder 3 by 3 in. shall be drilled axially to a diameter of $1\frac{1}{2}$ in. and a depth of $2\frac{1}{2}$ in. The bottom of the hole shall be made perfectly flat and the entire inner surface brought to a smooth finish. The pestle shall be made from a rod originally $1\frac{1}{2}$ in. in diameter by 5 in. long, and shall be smoothly faced and turned to a final diameter slightly less than $1\frac{1}{2}$ in. The mortar and pestle shall be heated for several hours in a laboratory muffle furnace at 750 to 800° C. and hardened by quenching in oil. The upper part of the pestle shall be slightly softer than the remainder in order to decrease the tendency to shatter. Both tools shall be polished with abrasive paper for the removal of scale. Such a mortar and pestle, together with an air hammer will pulverize alloys which will resist other equipment.

Other approved methods for the preparation of the pulverized sample from the gross sample may be substituted for the above provided they do not lead to contamination or loss of any portion of it. For example, the gross sample may be crushed entirely by rolls or in the absence of power machinery may be broken by hand to the required size. In the entire absence of power equipment the gross sample should be sent to a point where suitable facilities are available.

STANDARD METHODS OF CHEMICAL ANALYSIS OF FERRO-ALLOYS[1]

Serial Designation: A 104 – 27

These methods are issued under the fixed designation A 104; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1925; ADOPTED, 1927.

FERRO-SILICON

DETERMINATION OF SILICON BY FUSION WITH SODIUM PEROXIDE AND DEHYDRATION WITH HYDROCHLORIC ACID

Transfer 0.5000 g. (use 0.4000 g. for 90-per-cent silicon) of the finely powdered sample (passing a No. 150 sieve[2]) to a 50-cc. pure iron crucible made from No. 20 gage (0.32 in. thickness) ingot iron, add approximately 13 g. of sodium peroxide. Mix *thoroughly* with a platinum or iron rod and carefully clean the rod of adhering particles by scraping with another rod. Cover the mixture with a layer of about 2 g. of additional peroxide. Heat the crucible and contents on a hot plate for 5 to 10 minutes to expel any water in the peroxide which would cause spattering in the subsequent fusion. Carefully fuse over a low flame by holding the crucible with a pair of tongs and slowly revolving it around the outer edge of the flame until the contents have melted down quietly. When the fusion is molten rotate the crucible carefully to stir up any unattacked particles on the bottom or sides, the crucible and contents being maintained at a low red heat. Just before completion of the fusion, which requires

[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee A-9 on Ferro-Alloys.

[2] For detailed specifications for this sieve, see Standard Specifications for Sieves for Testing Purposes (Serial Designation: E 11) of the American Society for Testing Materials, see p. 789.

only three or four minutes, increase the temperature to bright redness for a minute. If the reaction has proceeded too violently, due to too rapid heating, to the use of insufficient sodium peroxide, or to the lack of thorough mixing, appreciable loss will occur and the work should be repeated.

Cover the crucible and allow it to cool until the fusion has solidified, and tap the crucible, while still warm, several times on an iron plate, which will loosen the fused mass in a solid cake. When the crucible and cake have completely cooled, transfer the cake to a large (275-cc.) gold or preferably platinum dish. Cover the dish with a clock glass and cautiously add 50 cc. of cold water. When the reaction ceases, wash the small amount of adhering matter in the crucible into the dish with a little water. Cool the solution and carefully add an excess of hydrochloric acid. Evaporate to dryness, preferably on a steam bath, but do not bake at a temperature above 110° C. If platinum or gold dishes are not available for solution of the fused cake, the latter can be disintegrated with water in a pure nickel dish and the contents then transferred to a porcelain dish containing sufficient hydrochloric acid to provide an excess of acid. It is not desirable to dissolve the fusions directly in porcelain, because of the action of the alkaline solution.

When the residue is dry, allow the dish to cool. Add 10 cc. of hydrochloric acid (sp. gr. 1.13), cover the dish and heat gently for a few minutes. Dilute with 100 cc. of hot water, digest for a few minutes and filter through an 11-cm. paper. Wash about eight times with hot 5-per-cent hydrochloric acid, three times with warm 5-per-cent sulfuric acid and a few times with hot water. Reserve this paper until the second evaporation has been completed.

Evaporate the filtrate to dryness and bake the covered casserole or dish at 110° C. for one hour. Heating at a higher temperature is unnecessary and also disadvantageous. Cool, add 10 cc. of hydrochloric acid (1:1), digest on the steam bath for ten minutes, add 100cc. of warm water, filter immediately and wash about eight times with cold 1-per-cent hydrochloric acid, twice with cold 5-per-cent sulfuric acid and a few times with cold water.

Place the paper and silica from the *second* dehydration in a large partially covered platinum crucible and char the paper without inflaming. Add the paper containing the silica from the first dehydration, char as before and then ignite carefully until the carbon has been burned off. Great care should be exercised in igniting the papers as the current of air produced by a burning filter is sufficient to carry finely divided silica out of the crucible. When the carbon

of the filter paper has been completely burned, gradually heat the tightly covered crucible to the full heat of a blast lamp and continue the heating at 1050 to 1100° C. for 25 minutes. Cool in a desiccator, weigh and check for constant weight by ten minutes additional heating at the above temperature. Add sufficient sulfuric acid (1:1) to moisten the silica and then 15 to 20 cc. of pure hydrofluoric acid (48-per-cent). Evaporate to dryness, ignite and weigh. The loss represents silica which contains 46.72 per cent of silicon. A blank, not omitting the same amount of hydrofluoric acid, should be carried through all stages of the operation.

NOTE

The silica remaining in the filtrate after the second dehydration is practically negligible, averaging about 0.0006 to 0.0010 g. in hydrochloric dehydration and 0.0010 to 0.0015 g. in sulfuric dehydration.

FERRO-MANGANESE

DETERMINATION OF MANGANESE BY THE MODIFIED BISMUTHATE METHOD[1]

REAGENTS REQUIRED

Dilute Nitric Acid (sp. gr. 1.135).—Mix 300 cc. of nitric acid (sp. gr. 1.42) and 700 cc. of distilled water. Test for proper specific gravity.

Dilute Nitric Acid (3 : 97).—Mix 30 cc. of recently boiled nitric acid (sp. gr. 1.42) and 970 cc. of distilled water. Add a little sodium bismuthate and shake well.

Asbestos.—Asbestos for this work should be digested in hot nitric acid (sp. gr. 1.42) and then washed free from acid with distilled water.

Sodium Bismuthate.—This reagent should be of 80-per-cent grade and its oxidizing power tested as follows: Shake 0.5 g. of the reagent with 4 g. of potassium iodide and a little water in a stoppered flask. Add 15 cc. of hydrochloric acid and allow to stand in the dark, with occasional shaking until the bismuthate has entirely decomposed. Dilute to 300 cc. and titrate with 0.1 *N* sodium thiosulfate, using starch as an indicator at the end. One cubic centimeter of 0.1 *N* $Na_2S_2O_3$ equals 0.0140 g. of $NaBiO_3$.

[1] *Journal of Industrial and Engineering Chemistry*, Vol. 16, p. 58 (1924).

Standard Potassium Permanganate Solution.—See the Determination of Chromium in Ferro-Chromium.[1] One cubic centimeter of 0.1 *N* $KMnO_4$ equals 0.001099 g. of manganese.

METHOD

(*A*) *Solution of the Sample*

All samples should be crushed to approximately a size to pass a No. 100 sieve and dried at 105 to 110° C.

With high-carbon 80-per-cent ferro-manganese, dissolve 0.25 g. of the prepared sample in 60 cc. of nitric acid (sp. gr. 1.42) in a 750-cc. Erlenmeyer flask, provided with a clock-glass cover or trap to prevent loss by spraying.

Add 2 g. of potassium nitrate and boil gently until the volume of the solution has been reduced to about 15 cc. Cool, add 10 cc. of H_2SO_4 (1:1) and evaporate to strong fumes of sulfuric acid. Cool somewhat, dilute the solution with 200 cc. of HNO_3 (sp. gr. 1.135), heat to boiling, remove from the heat and add sodium bismuthate a little at a time until a precipitate of manganese dioxide has formed. When this occurs, add sulfurous acid dropwise until the precipitate has dissolved and an excess of about 1 cc. has been provided to reduce any chromium to the trivalent form. Boil the solution about five minutes to completely expel oxides of nitrogen, dilute to 250 cc. with water, cool the flask and solution in crushed ice and treat as described later. High-carbon ferro-manganese containing 1 per cent or more of chromium may not dissolve completely in nitric acid. In this case, dilute the solution after treatment with nitric acid, filter, and fuse the washed residue with a little sodium carbonate. Dissolve the melt in a small volume of nitric acid (sp. gr. 1.135), and add it to the main solution. Treat with potassium nitrate, etc., as previously described.

With low-carbon ferro-manganese or manganese metal dissolve 0.2500 g. of the sample in 250 cc. of nitric acid (sp. gr. 1.135) in a covered 750-cc. Erlenmeyer flask and boil the solution gently for a few minutes to expel oxides of nitrogen. Treat with bismuthate and sulfurous acid as described above.

With silico-manganese (60 to 70 per cent of manganese) and manganese-silicon (20 to 25 per cent of manganese) treat 0.3000 g. of the former and 1.000 g. of the latter with 5 cc. of hydrofluoric acid in a large platinum dish equipped with a gold or platinum cover. (Some spiegeleisens are completely soluble in nitric acid in which

[1] See p. 497.

case the sample can be dissolved directly in 250 cc. of nitric acid (sp. gr. 1.135). When the reaction moderates, add nitric acid (sp. gr. 1.42) a few drops at a time until the sample has completely dissolved. Add 10 cc. of nitric acid (sp. gr. 1.42) and evaporate to a syrupy consistency. Again add 10 cc. of nitric acid (sp. gr. 1.42) and evaporate as before to expel hydrofluoric acid. Dissolve the residue in nitric acid (sp. gr. 1.135), transfer to a 750-cc. Erlenmeyer flask, dilute with nitric acid (sp. gr. 1.135) to 250 cc. and treat as described before with sodium bismuthate, etc.

(B) Oxidation of Manganese

If the preceding directions have been followed, the manganese will be present in a concentration of approximately 0.001 g. per 1 cc. of nitric acid (sp. gr. 1.135). This concentration of manganese and nitric acid, together with a temperature of 10 to 15° C. are the conditions which insure maximum stability of the permanganic acid, formed as further described. To insure complete oxidation of the manganese to permanganic acid, it is essential that the sodium bismuthate (80 per cent of $NaBiO_3$) be used in the ratio of at least 26 g. to every gram of manganese in solution. Add approximately 7.0 g. of sodium bismuthate (80-per-cent) to the flask, *agitate briskly* for one minute, dilute with 250 cc. of cold water, and filter immediately on a layer of acid-washed asbestos supported on a 2-in. alundum or perforated porcelain plate resting in a large glass funnel. The filter can be washed free from manganese more readily if not allowed to run dry during the filtering and washing. Wash the filter and residue with cold 3-per-cent nitric acid until the washings are entirely colorless and immediately treat the filtrate and washings as described in the following paragraph.

Weigh accurately 9.000 g. of ferrous ammonium sulfate, taken from a bottle of the well-mixed salt, and add to the filtered solution of permanganic acid. Stir briskly and as soon as the reduction is complete and the salt has dissolved, titrate the excess of ferrous salt with 0.1 *N* potassium permanganate. The manganese value of the ferrous salt is obtained in the following manner:

Two hundred and fifty cubic centimeters of nitric acid (sp. gr. 1.135) contained in a 750-cc. Erlenmeyer flask are treated with approximately 2.0 g. of sodium bismuthate and the solution is vigorously agitated for one minute, diluted with 250 cc. of cold water, and immediately filtered on a layer of acid-washed asbestos as previously described. Five (5.000) grams of the ferrous ammonium sulfate are added to the filtrate and the resulting solution is immediately titrated

with 0.1 *N* $KMnO_4$ until a faint pink color appears. The excess of permanganate used to cause an end point color must be determined by watching the color in another beaker containing the same amounts of acid and cold water.

NOTES

1. Chromium when less than 2 per cent does not cause any interference if the reactions are rapidly done in cold solutions. Larger amounts interfere to some extent and should be separated prior to the final oxidation with bismuthate.

2. The gravimetric determination of manganese by the pyrophosphate method will give high values if the precipitate of manganese ammonium phosphate is allowed to stand more than ten hours before filtration.

3. Volumetric methods such as Volhard's, Ford-Williams' and Julian's do not permit the use of a theoretical titre. Each necessitates the use of an empirical titre obtained by titration of material of known manganese content which has been carried through all steps of the method.

DETERMINATION OF CARBON BY THE DIRECT-COMBUSTION METHOD

See the Determination of Carbon in Ferro-Chromium by the Direct-Combustion Method.[1] A furnace temperature of 1050 to 1075° C. suffices, and high-silicon material should be covered with 1 or 2 g. of ingot iron.

DETERMINATION OF PHOSPHORUS BY THE ALKALIMETRIC METHOD

SOLUTIONS REQUIRED

Dilute Nitric Acid (sp. gr. 1.135).—Mix 300 cc. of HNO_3 (sp. gr. 1.42) and 700 cc. of distilled water.

Ammonium Molybdate.—See the Determination of Phosphorus in Ferro-Vanadium by the Modified Molybdate-Magnesia Method.[2]

Standard Sodium Hydroxide.—Dissolve 6.5 g. of purified NaOH in 1000 cc. of distilled water, add a slight excess of a 1-per-cent solution of $Ba(OH)_2$, let stand for 24 hours, decant the liquid and standardize against Bureau of Standards Standard Benzoic Acid as follows: Dissolve 0.6 g. of benzoic acid in 15 cc. of alcohol in a small Erlenmeyer flask and titrate in the cold with phenolphthalein indicator,

[1] See p. 500.
[2] See p. 503.

taking precautions to prevent access of carbon dioxide from the air during titration. The ratio of phosphorus to sodium hydroxide is taken as 1 to 23 in calculating the value of the sodium hydroxide. Protect the solution from carbon dioxide with a soda-lime tube.

Standard Nitric Acid.—Mix 10 cc. of HNO_3 (sp. gr. 1.42) and 1000 cc. of distilled water. Titrate the solution against the standard hydroxide solution, using phenolphthalein as an indicator. Adjust the solution so that it is equivalent to the sodium hydroxide solution.

Dilute Ammonium Hydroxide (sp. gr. 0.96).—Dilute 400 cc. of NH_4OH (sp. gr. 0.90) with 600 cc. of water. The strength of this solution should be established by titration or test with a hydrometer.

METHOD

Dissolve 2.000 g. of the sample in 70 cc. of nitric acid (sp. gr. 1.42), evaporate to dryness and bake for two or three hours at 120° C. High-silicon alloys may require the addition of a little hydrofluoric acid for complete decomposition. In this case, several evaporations with 15-cc. portions of nitric acid (sp. gr. 1.42) should be made to remove hydrofluoric acid before the baking treatment. Moisten the residue with 25 cc. of dilute hydrochloric acid (1:1), digest a few minutes,[1] add 75 cc. of water, heat until the salts are dissolved and then filter to remove silica. Evaporate the filtrate to a syrupy condition, add 15 cc. of nitric acid (sp. gr. 1.42) and again evaporate to a small volume. Again add 15 cc. of nitric acid (sp. gr. 1.42) and evaporate to a small volume. Add 100 cc. of nitric acid (sp.gr. 1.135), heat to boiling and add a 1.5-per-cent solution of potassium permanganate until oxides of manganese are precipitated. Dissolve the oxides of manganese by addition of sulfurous acid and boil to expel the oxides of nitrogen. To the cold solution add 40 cc. of NH_4OH (sp. gr. 0.96) and 50 cc. of ammonium molybdate solution and shake for 5 minutes. Allow to settle for 10 minutes; for material containing less than 0.02 per cent of phosphorus, allow to stand 30 minutes. Filter and wash 10 times with a 1-per-cent solution of KNO_3. Return the precipitate and paper to the precipitating vessel, add 1 to 3 cc. in excess of standard NaOH solution and 25 cc. of water, both free from carbon dioxide, and shake or stir until the precipitate is dissolved. Dilute to 100 cc. with water free from carbon dioxide, add 3 drops of a 0.2-per-cent solution of phenolphthalein, and discharge the pink color with standard acid. Finish the titration by adding standard alkali until the reappearance of the pink color. With very

[1] Addition of a little sulfite or sulfurous acid facilitates solution after the baking treatment.

low phosphorus material this titration should be corrected by a blank carried through all steps of the method.

NOTE

If vanadium is present in amounts over 0.08 per cent it should be reduced by ferrous sulfate and sulfurous acid before precipitation with molybdate.

DETERMINATION OF SULFUR BY THE OXIDATION METHOD

Proceed as in the Determination of Sulfur by the Oxidation Method as described in the Standard Methods of Chemical Analysis of Plain Carbon Steel (Serial Designation: A 33) of the American Society for Testing Materials.[1]

NOTES

Routine determinations of sulfur can be made by the evolution method provided concentrated hydrochloric acid (sp. gr. 1.19) is used, preferably in all-glass apparatus of the Pulsifer type.

DETERMINATION OF SILICON BY THE NITRO-SULFURIC ACID METHOD

SOLUTIONS REQUIRED

Nitro-Sulfuric Acid.—Pour 160 cc. of sulfuric acid (sp. gr. 1.84) slowly and with stirring into 660 cc. of water and add 180 cc. of nitric acid (sp. gr. 1.42).

METHOD

Dissolve 0.9344 g. of the sample passing a No. 100 sieve[2] with 50 cc. of the nitro-sulfuric acid in a 250-cc. porcelain casserole and evaporate until copious fumes of sulfuric acid are evolved. After the solution has cooled somewhat add 125 cc. of distilled water and 5 cc. of HCl (sp. gr. 1.19). Heat with frequent stirring until all salts are dissolved and immediately filter on a 9-cm. paper. Wash the precipitate with cold dilute HCl (5:95) and hot water alternately to complete the removal of soluble salts, and finally with hot water until free from acid. Transfer the filter to a platinum crucible, char the paper carefully, and finally ignite with the crucible covered over a blast lamp or in a muffle furnace at 1050 to 1100° C. for at

[1] See p. 276.

[2] For detailed specifications for these sieves, see Standard Specifications for Sieves for Testing Purposes (Serial Designation: E 11) of the American Society for Testing Materials, see p. 789.

least 10 minutes; cool in a desiccator and weigh. Add sufficient dilute sulfuric acid (1:1) to moisten the silica and then a small amount of hydrofluoric acid. Evaporate to dryness, ignite and weigh. The difference in weights divided by 2 and multiplied by 100 represents the percentage of silicon in the alloy.

NOTE

For silico-manganese and manganese-silicon, fuse 0.4672 g. of the former or 0.2336 g. of the latter with 8 g. of sodium peroxide in a pure iron crucible. Dissolve the fusion and evaporate to fumes of sulfuric acid. When acidifying the solution of the fusion with sulfuric acid it is necessary to add some sulfurous acid to dissolve the manganese dioxide which separates out.

FERRO-CHROMIUM

DETERMINATION OF CHROMIUM BY FUSION WITH SODIUM PEROXIDE

SOLUTIONS REQUIRED

Potassium Permanganate, 0.1 N.—Dissolve 3.2 g. of potassium permanganate in 1000 cc. of distilled water, allow to age for at least ten days and filter through purified asbestos. Standardize the permanganate solution against Bureau of Standards Standard Sodium Oxalate as follows:

In a 400-cc. beaker dissolve 0.25 to 0.30 g. of sodium oxalate in 200 to 250 cc. of hot water (80 to 90° C.) and add 10 cc. of dilute H_2SO_4 (1:1). Titrate at once with the permanganate solution, stirring the liquid vigorously and continuously. The permanganate must not be added more rapidly than 10 to 15 cc. per minute, and the last 0.5 to 1 cc. must be added dropwise, with particular care to allow each drop to fully decolorize before the next is introduced. The excess of permanganate used to cause an end point color must be estimated by matching the color in another beaker containing the same bulk of acid and hot water. The temperature of the solution should not be below 60° C. by the time the end point is reached. One cubic centimeter of 0.1 *N* $KMnO_4$ is equivalent to 0.001734 g. of chromium.

Standard Ferrous Ammonium Sulfate.—Dissolve 43 g. of the salt in 250 cc. of cold water, add 40 cc. of sulfuric acid (1:3), dilute to one liter with distilled water, and mix thoroughly. Large amounts of the solution can be conveniently mixed by means of a stream of carbon dioxide from a cyclinder. As the ferrous ammonium sulfate solution gradually weakens in reducing power it is necessary to standardize it daily or at the same time the ferro-chromium is analyzed.

The solution can be standardized against either potassium dichromate or sodium oxalate.

The first method is somewhat simpler and more satisfactory for routine work as the conditions prevailing in both the standardization and in the analysis are practically identical. No "blank" corrections are afterwards necessary where the amounts of dichromate, ferrous salt and permanganate are approximately those prevailing in the analysis. The second method is employed chiefly for checking the accuracy of the results obtained with potassium dichromate and in cases where only occasional analyses are made and pure dichromate is not readily available.

To prepare pure potassium dichromate, recrystallize at least twice the purest grade of the salt obtainable, dry the crystals at 150° C., grind to a fine powder and again dry at 150° C. to constant weight. Keep the prepared salt in a ground-glass stoppered bottle. Transfer 1.0000 g. of the pure dichromate, which contains approximately the same amount of chromium as an 0.5000-g. sample of 70-per cent ferro-chromium, to an 800-cc. beaker. Dissolve in cold water, acidify with 40 cc. of sulfuric acid (1:3) and dilute with cold water to 500 cc. Add a slight excess of the ferrous sulfate solution, approximately 190 cc., and titrate the excess ferrous salt with 0.1 *N* permanganate to the first faint permanent darkening of the clear green color.

Example.—The calculations involved are illustrated as follows: In a standardization, 190.0 cc. of the ferrous solution was used and 5.06 cc. of 0.1 *N* permanganate was required to titrate the excess.

1 cc. of 0.1 *N* $K_2Cr_2O_7$ contains 0.004903 g. of $K_2Cr_2O_7$

1 g. of $K_2Cr_2O_7$ equals 203.94 cc. of 0.1 *N* $K_2Cr_2O_7$

then:

203.94 + 5.06 = 209.0 cc. of equivalent 0.1 *N* solution reduced by the ferrous solution.

$$\frac{209.0}{190} = 1.100, \text{ the 0.1 } N \text{ normality factor.}$$

In standardizing through sodium oxalate, it is necessary to add the ferrous ammonium sulfate solution by means of an accurately calibrated pipette or burette instead of an automatic pipette. Transfer 100 cc. of the approximately 0.1 *N* ferrous solution to a 600-cc. beaker, dilute to 300 cc. with cold 5-per-cent sulfuric acid, add 2 cc. of phosphoric acid and titrate immediately with 0.1 *N* $KMnO_4$ to a faint permanent pink color. Determine the "blank" on the same volume of water and acids and deduct. When this method is used it is necessary in the actual analysis to determine a "blank" to counteract the influence of the green color of the chromium sulfate upon the permanganate end point. This "blank" can be determined in the solution used in the analysis and is obtained as described later.

METHOD

Transfer 0.5000 g. of the sample of ferro-chromium (dried at 105 to 110° C.) to a 30-cc. heavy-walled porcelain crucible. Samples of low-carbon ferro-chromium should be crushed to pass through a No. 40 screen, while high-carbon ferro-chromium and chromium metal should be reduced to pass a No. 100 screen. Add approximately 8 g. of sodium peroxide and thoroughly mix the contents of the crucible with a small rod, being careful to clean the rod, which can be done conveniently by scraping with another rod. Cover the mixture with 1 to 2 g. of sodium peroxide. Carefully fuse the contents of the covered crucible, preferably in an electric muffle heated to 600 to 700° C. Fusion for five minutes at a low red heat after the mass has melted will insure complete decomposition. When the charge has melted, the crucible should be given a slight rotary motion to stir up any unattached particles.

Place the cooled crucible and cover in a 600-cc. beaker and dissolve the contents in 200 cc. of water. When the melt has dissolved, remove the crucible and cover, add 1 g. of sodium peroxide and boil the solution ten minutes to completely decompose the excess of peroxide.

Allow the precipitate to settle and filter through a pad of ignited asbestos, preferably in a Büchner funnel. An asbestos rather than a paper filter should be used, for the alkaline solution extracts reducing matter from paper which would cause low results for chromium. Thoroughly wash the precipitate with hot water, and at no time allow the precipitate to run dry during the filtering and washing. If desired, the precipitate can be subsequently dissolved in dilute sulfuric acid and tested for chromium by adding a slight excess of sodium peroxide; the amount of chromium retained is negligible if the precipitate is filtered and washed as directed.

Cool the filtrate, acidify with 50 cc. of sulfuric acid (1:1), again cool to room temperature, transfer to an 800-cc. beaker, dilute with cold water to 500 cc. and add a measured excess of ferrous ammonium sulfate. The point at which reduction is complete can be told by changes in the deep green color which is developed. The ferrous salt can be added either as an approximately 0.12 *N* solution or in weighed portions from a bottle of the well-mixed salt. If the solution of ferrous salt is used, approximately 180 cc. will be required for a 70-per-cent alloy; if the salt is added, 8 g. will usually be sufficient. Titrate the excess of ferrous salt with standard 0.10 *N* potassium permanganate. The first faint permanent darkening of the clear green color is taken as the end point, which is quite sharp and well defined to the practiced eye. If the ferrous salt has been standardized

against dichromate, subtract the required number of cubic centimeters of 0.1 *N* permanganate from the number of cubic centimeters of 0.1 *N* ferrous solution (obtained by multiplying the number of cubic centimeters of the approximately 0.1 *N* ferrous solution by the 0.1 *N* normality factor). The difference represents the number of cubic centimeters of 0.1 *N* ferrous solution which multiplied by 0.001733 g. gives the number of grams of chromium present.

Where the ferrous solution has been standardized against sodium oxalate, it is necessary to subtract a "blank" from the permanganate titration. This "blank" is obtained as follows: When the end point is reached and the readings have been noted, add about 5 cc. in excess of the ferrous solution and oxidize the excess of ferrous iron by adding 8 cc. of a 15-per-cent solution of ammonium persulfate. *Stir the liquid vigorously for one minute.* Carefully add 0.1 *N* permanganate to the solution with constant stirring until the same end point is obtained as before. The volume of permanganate required, usually 0.2 to 0.4 cc., constitutes the "blank" to be deducted from the volume of the permanganate titration. For example, in the determination of chromium in an 0.5000-g. sample, 190.0 cc. of a 0.11 *N* ferrous solution and 11.00 cc. of an 0.1 *N* permanganate (11.40 − 0.4 cc. blank) were employed.

The calculations are as follows:

$190.0 \times 1.100 = 209.0$ cc. of 0.1 *N* ferrous solution
$209.0 - 11.0 = 198.00$ cc.
$198.0 \times 0.001734 \times 2 \times 100 = 68.65$ per cent of chromium

The above calculations are given for exactly 0.1 *N* permanganate; if the permanganate is not 0.1 *N*, the volume used must be converted to the equivalent of 0.1 *N* by multiplying by the proper factor.

DETERMINATION OF CARBON BY THE DIRECT-COMBUSTION METHOD

Determine carbon by the direct-combustion method described in the Standard Methods of Chemical Analysis of Plain Carbon Steel (Serial Designation: A 33) of the American Society for Testing Materials,[1] with the following modifications:

1. Ferro-chromium alloys require a furnace temperature of 1125 to 1150° C. in order to yield all of the carbon in the material.

2. The determination is made as given in the reference except that the weighed sample of ferro-chromium, 0.5000 g. for 4 to 8-per-cent carbon and 3 to 1 g. for 0.10 to 2.00-per-cent carbon, is mixed

[1] See p. 276.

with 1 g. of copper oxide and covered with 2 g. of pure ingot iron drillings in order to facilitate complete combustion.

3. On account of the small weight of sample used, the blanks are important and must be carefully determined.

DETERMINATION OF SILICON

Low-carbon ferro-chromium and chromium metal can be decomposed by means of dilute sulfuric acid, but the high-carbon alloy has to be fused with sodium peroxide. For low-carbon ferro-chromium, transfer 0.9344 g. (a double factor weight) to a 250-cc. porcelain casserole, add 60 cc. of sulfuric acid (1:4) and warm the covered casserole gently until the reaction is complete. For high-carbon ferro-chromium, transfer 0.9344 g. of the sample passing a No. 100 sieve to a 30-cc. pure iron crucible made from No. 20 gage (0.032 in. thickness) ingot iron. Add approximately 8 g. of sodium peroxide, mix thoroughly and fuse as directed under the determination of chromium. When the fusion has solidified, tap the covered crucible, while still warm, on an iron plate to loosen its contents in a solid cake which is then transferred to a 250-cc. casserole. Rinse the crucible with a little water, transfer the solution to the casserole, cover, and carefully add 60 cc. of sulfuric acid (1:4) after which the cover glass is rinsed and removed.

Evaporate the solution obtained by either of the above procedures until fumes of sulfuric acid are given off. If chromium sulfate solutions are fumed at too high temperatures or for any great length of time or with too little free acid present, considerable difficulty will occur in dissolving the salts. The fuming should, therefore, be made at a temperature not much higher than that required for evolving the acid. Allow the casserole and contents to partly cool (if permitted to become entirely cold, difficulty may be experienced in getting chromium salts to dissolve), add 100 cc. of warm water while stirring to prevent the residue from caking on the bottom and boil the solution gently for several minutes to dissolve all salts. Filter, washing the paper several times with cold dilute hydrochloric acid (2-per-cent), and then with warm water. Transfer the filter and contents to a platinum crucible, char the paper, carefully ignite to remove carbon, and then heat the covered crucible over a blast lamp or in a muffle furnace at 1050 to 1100° C. for at least 15 minutes. Cool in a desiccator and weigh. Add sufficient dilute sulfuric acid (1:1) to moisten the silica and then a small amount of hydrofluoric acid. Evaporate to dryness, ignite and weigh. The difference in weights represents silica which contains 46.72 per cent of silicon.

NOTE

Crucibles made from pure ingot iron contain only traces of silicon and the amount of silica present in the sodium peroxide used is usually negligible, but "blanks" should be run on new lots of crucibles and of peroxide. All nickel crucibles, even the German "Rein" nickel, contains appreciable amounts of silicon.

FERRO-VANADIUM

DETERMINATION OF VANADIUM BY THE AMMONIUM PERSULFATE METHOD

SOLUTIONS REQUIRED

Ammonium Persulfate (15-per-cent).—Make up as needed by dissolving 15 g. of the salt in 100 cc. of distilled water. This salt should be 95-per-cent pure and its purity tested by adding 30 cc. of a standard ferrous sulfate solution to 0.3 g. of the persulfate, then 200 cc. of hot water and titrating the excess ferrous salt with potassium permanganate. One cubic centimeter of 0,1 *N* ferrous solution equals 0.01141 g. of $(NH_4)_2S_2O_8$.

Potassium Ferricyanide Indicator.—Dissolve 0.1 g. of the salt in 100 cc. of water. This solution should be made up fresh daily.

Standard Ferrous Ammonium Sulfate (approximately 0.1 N).—See the Determination of Chromium in Ferro-Chromium.[1]

Potassium Permanganate (0.1 N).—See the Determination of Chromium in Ferro-Chromium.[1] One cubic centimeter of 0.1 *N* $KMnO_4$ is equivalent to 0.005096 g. of vanadium in the following method.

METHOD

Treat 0.5000 g. of the alloy, dried at 105 to 110° C., in a 250-cc. covered beaker with a mixture of 60 cc. of sulfuric acid (1:3) and 25 cc. of nitric acid (1:1). If the alloy fails to decompose readily because the silicon content is high, it may be necessary to add a small amount of hydrofluoric acid. In this event, a 200-cc. platinum dish should be substituted for the beaker. When the reaction has abated, rinse the cover glass and evaporate the solution until copious fumes of sulfuric acid are evolved. Cool, add 100 cc. of water and heat until the salts are dissolved. Transfer the solution to an 800-cc. beaker, dilute to 400 cc. and to the cooled solution add an approximately 0.1 *N* solution of potassium permanganate until a strong pink color has developed which remains permanent for thirty seconds.

[1] See p. 497.

Next reduce the vanadium by the use of an approximately 0.1 *N* solution of ferrous ammonium sulfate added until a drop of the solution withdrawn from the beaker and placed on a drop of potassium ferricyanide indicator shows ferrous iron present—about 35 cc. of 0.1 *N* ferrous solution. Add 5 cc. of the ferrous ammonium sulfate in excess, stir the solution at least one minute, oxidize the excess of ferrous sulfate with 8 cc. of 15-per-cent ammonium persulfate and stir the solution vigorously for *one minute*. Titrate the solution with 0.1 *N* potassium permanganate solution, added with constant stirring until a faint pink color appears which remains permanent for 30 seconds. Determine the "blank" by dissolving 0.4 g. of "ingot iron" in 60 cc. of H_2SO_4 (1:3) and 5 cc. of nitric acid (sp. gr. 1.42), and putting the solution through all of the operations of the analysis. If the alloy contains an appreciable amount of chromium, a weight of pure $K_2Cr_2O_7$ equivalent to the amount of chromium in the sample is dissolved in the acids with the ingot iron.

DETERMINATION OF CARBON

See the Determination of Carbon in Ferro-Chromium by the Direct-Combustion Method.[1] A furnace temperature of 1050 to 1100° C. will suffice for ferro-vanadium and complete combustion except in very high-silicon material can be secured without the addition of ingot iron and copper oxide.

DETERMINATION OF PHOSPHORUS BY THE MODIFIED MOLYBDATE-MAGNESIA METHOD

SOLUTIONS REQUIRED

Ammonium Molybdate.—

Solution No. 1.—Place in a beaker 100 g. of 85-per-cent molybdic acid, mix thoroughly with 240 cc. of distilled water, add 140 cc. of NH_4OH (sp. gr. 0.90), filter, and add 60 cc. of HNO_3 (sp. gr. 1.42).

Solution No. 2.—Mix 400 cc. of HNO_3 (sp. gr. 1.42) and 960 cc. of distilled water.

When the solutions are cold, add Solution No. 1 to Solution No. 2, stirring constantly, then add 0.1 g. of ammonium phosphate dissolved in 10 cc. of distilled water, and let stand at least 24 hours before using.

[1] See p. 500.

Magnesia Mixture.—Dissolve 50 g. of $MgCl_2 \cdot 6H_2O$ and 200 g. of NH_4Cl in 1000 cc. of distilled water containing a few cubic centimeters of hydrochloric acid.

METHOD

Transfer 4 g. of the sample to a platinum dish of 150 to 200-cc. capacity, add 70 cc. of dilute HNO_3 (5:6) and heat the covered dish until vigorous action ceases. Add 1 or 2 cc. of hydrofluoric acid, stir the solution, evaporate to dryness, moisten with 10 cc. of nitric acid (sp. gr. 1.42) and again evaporate to dryness. Moisten the cooled residue with 10 cc. of HNO_3 (sp. gr. 1.42), add 50 cc. of water and wash the contents of the dish into a 400-cc. beaker, rubbing the dish well with a policeman. Remove the last traces of adhering salts with 5 cc. of HCl (sp. gr. 1.19) and hot water. Add 10 cc. of HNO_3 (sp. gr. 1.42) and evaporate to a syrupy consistency. Cool, add 25 cc. of HNO_3 (sp. gr. 1.42) 60 cc. of water, 1 g. of boric acid (to take care of any residual fluoride) and heat gently until solution occurs. Filter through a rapid paper into a 300-cc. Erlenmeyer flask and wash with hot water. Heat the solution to boiling, add about 12 cc. of potassium permanganate solution (1.5-per-cent) and continue the boiling until manganese dioxide precipitates. Dissolve the precipitate by the addition of sufficient sulfurous acid added dropwise. About 1 cc. usually suffices. Boil for a few minutes to completely expel oxides of nitrogen. Add to the cold solution 15 cc. of ammonium hydroxide (sp. gr. 0.90) and cool the solution to 15° C.

Next reduce the vanadium in the cold (15° C.) solution by ferrous sulfate added in approximately 1.5 g. excess. The use of a 50-per-cent solution of the salt furnishes a convenient way of adding the necessary amount. One gram of quinquevalent vanadium requires 5.5 g. of $FeSO_4 \cdot 7H_2O$ for reduction to the quadrivalent state. A 4-g. sample of 30-per-cent vanadium alloy, including an excess of 1.5 g., would require 8.1 g. of ferrous sulfate. Too large an excess of ferrous sulfate should be avoided. The addition of ferrous sulfate will change the color of the solution to a deep blue. Add 2 drops of a saturated solution of sulfurous acid, 100 cc. of molybdate reagent, shake for 10 minutes and allow to stand at 15° C. for 4 to 6 hours, or preferably overnight. It is well to let the solution stand in a refrigerator. Filter on a paper of close texture, keeping as much of the precipitate in the flask as possible, and wash the flask and the precipitate with not more than 50 cc. of cold, dilute nitric acid (1:99). Set the filtrate and washings aside after thorough mixing and see whether further separation of phosphomolybdate occurs. Dissolve the precipitate on the

filter in 20 cc. of dilute ammonium hydroxide (1:1) to which have been added 2 g. of citric acid, catch the solution in the original flask containing the bulk of the yellow precipitate and finally wash the filter several times with dilute hydrochloric acid (5:95). If the ammoniacal solution of the phosphomolybdate is not clear at this point, heat it to boiling, filter through the same paper, and wash the paper with hot water. In this case, and whenever appreciable amounts of such elements as titanium or zirconium are known to be present in the original material, preserve the paper and ignite it in a small platinum crucible with the paper reserved below.

Render the ammoniacal solution acid with hydrochloric acid, add 20 cc. of magnesia mixture and then ammonium hydroxide (sp. gr. 0.90) slowly until a crystallin precipitate appears, and then finally an excess of 3 to 5 per cent by volume. The volume of the solution at this point should not exceed 100 cc. Allow the solution to stand in a cool place for 4 to 6 hours, or preferably overnight.

Filter, keeping as much of the precipitate as possible in the flask, and wash the flask and the precipitate moderately with dilute ammonium hydroxide (1:20). Set the filtrate and washings aside after thorough mixing and see whether further precipitation occurs. Dissolve the precipitate on the filter in 25 cc. of dilute hydrochloric acid (1:1), catching the solution in the original flask containing the bulk of the precipitate. Wash the filter thoroughly with dilute hydrochloric acid (5:95). In case the original material contains appreciable amounts of the elements mentioned above (titanium or zirconium), add the paper to the one reserved above, ignite, fuse any residue with as little carbonate as possible (not over 0.5 g.), extract the cooled melt with hot water, filter, and add the water solution to the hydrochloric acid solution. Transfer the solution to a 200-cc. beaker. In case the amount of arsenic is known to be very small, add 0.5 to 1 g. of ammonium bromide and boil the hydrochloric acid solution to a volume of 5 to 10 cc. Where large amounts of arsenic were originally present, treat with hydrogen sulfide, digest, filter, and wash with acidulated hydrogen sulfide water. Boil to expel hydrogen sulfide and to reduce the volume to 50 to 75 cc. Add 0.1 to 0.2 g. of citric acid, 2 to 3 cc. of magnesia mixture, make ammoniacal as above, and allow to stand in a cool place for 4 to 24 hours.

Filter, wash with dilute ammonium hydroxide (1:20), and ignite the precipitate carefully and at as low a temperature as possible until the carbon has been destroyed and the residue is white. Finally, ignite at approximately 1000° C. to constant weight. Dissolve the ignited residue in 5 cc. of dilute nitric acid (1:1) and 20 cc. of water.

Filter, wash the residue with hot water, ignite and weigh. Treat with a few drops of hydrofluoric acid, evaporate to dryness, ignite and re-weigh. Subtract any loss of weight from the original weight of the pyrophosphate, and calculate on the basis of this purified magnesium pyrophosphate.

DETERMINATION OF SULFUR BY THE OXIDATION METHOD

Transfer 4.57 g. of the sample to a 600-cc. beaker and dissolve it in 75 cc. of HNO_3 (sp. gr. 1.42). The reaction is apt to be very rapid and the acid should be added in small portions to the covered beaker which is preferably kept cooled by immersion in ice water. Effect complete solution by gentle warming if necessary.

Add 30 cc. of HCl (sp. gr. 1.19) and evaporate to dryness on the steam-bath. Add 30 cc. more of HCl (sp. gr. 1.19), again evaporate to dryness, and bake for 30 minutes at 105° C. Moisten the residue with 30 cc. of HCl (sp. gr. 1.19) and evaporate on the steam-bath to a volume of 5 cc. Add 5 cc. of HCl (sp. gr. 1.19), dilute to 150 cc. and filter. Wash with warm water.

Adjust the volume of the solution to 250 cc. which should now contain about 3 to 4 per cent by volume of HCl. Warm to 75° C., add 30 cc. of $BaCl_2$ (10-per-cent), and allow to stand for 24 to 40 hours.

Filter, with as little transfer of the precipitate as possible, through a paper of close texture. Wash the paper two or three times with cold 1-per-cent HCl and seven times with warm water. Ignite the paper and contents in a platinum crucible. Treat the ignited residue with 5 cc. of HCl (sp. gr. 1.19) and transfer the resulting solution to the original beaker containing most of the precipitate of $BaSO_4$. Digest the combined portions of $BaSO_4$ so as to dissolve any barium vanadate. Adjust to 150-cc. volume and 2-per-cent acidity, add 8 cc. of 10-per-cent $BaCl_2$ solution and allow to stand for 24 hours. Filter on a paper of close texture, wash three times with cold 1-per-cent HCl and 10 times with warm water. Ignite the paper in platinum, cool in a desiccator and weigh. A blank should be carried through all steps of the determination. The corrected weight of the ignited barium sulfate multiplied by three is equal to the percentage of sulfur.

NOTES

If desired, the washings can be kept separate and examined for $BaSO_4$ as follows: Evaporate the washings to dryness. Dissolve the slight residue in 50 cc. of hot dilute HCl (2:98), add 2 cc. of $BaCl_2$ solution (10-per-cent), digest at 70 to 80° C. for two hours, avoiding any undue evaporation. Filter on a small paper of close texture and wash as above. The recovery of $BaSO_4$, which is ordinarily obtained, represents approximately 0.001 to 0.002 per cent of sulfur.

In high-silicon alloys the residue from the initial acid digestion should be evaporated with hydrofluoric and nitric acids, fused with sodium carbonate and the water extract of the melt added to the main solution.

DETERMINATION OF SILICON BY THE NITRO-SULFURIC METHOD

SOLUTIONS REQUIRED

Nitro-Sulfuric Acid.—Pour 160 cc. of sulfuric acid, (sp. gr. 1.84) slowly and with stirring into 660 cc. of water, and add 180 cc. of nitric acid (sp. gr. 1.42).

METHOD

Dissolve 0.9344 g. of the sample passing a No. 100 sieve of low or medium-silicon ferro-vanadium in 40 cc. of the nitro-sulfuric acid in a 250-cc. porcelain or platinum dish and evaporate the solution until "copious" fumes of sulfuric acid are evolved.

Ferro-vanadium containing 4 per cent or more of silicon is not completely soluble in nitric acid and sulfuric acid. In this case, fuse 0.9344 g. of the alloy, thoroughly mixed with 8 g. of sodium peroxide, in a 30-cc. crucible of pure iron. Five minutes heating at a dull red heat after the contents of the crucible have melted will insure complete decomposition of the sample. Allow the fusion to solidify, but before it has entirely cooled tap the covered crucible on an iron plate which will loosen the contents in a solid cake. Transfer the melt to a 250-cc. porcelain casserole, rinse the crucible with warm water and cautiously add the solution to the covered casserole. Next add 150 cc. of sulfuric acid (20 per cent by volume) and evaporate to copious fumes of sulfuric acid. Cool the sulfuric acid solution obtained in either procedure, add 125 cc. of water and heat for a few minutes with frequent stirring until all salts are dissolved. Immediately filter on a 9-cm. paper. Wash the precipitate with cold dilute HCl (5:95) and cold water alternately to complete the removal of iron salts, and finally with hot water until free from acid. Transfer the filter to a platinum crucible, char the paper without inflaming and

finally ignite the covered crucible over a blast lamp or in a muffle furnace at 1050 to 1100° C. for at least 15 minutes. Cool in a desiccator and weigh. Add sufficient dilute H_2SO_4 (1:1) to moisten the silica and then a small amount of hydrofluoric acid. Evaporate to dryness, ignite and weigh. The difference in weights divided by 2 and multiplied by 100 represents the percentage of silicon in the alloy.

DETERMINATION OF ALUMINUM BY THE ETHER-HYDROCHLORIC ACID METHOD[1]

Dissolve 2 g. of the sample in 25 to 30 cc. of dilute nitric acid (sp. gr. 1.135) (Note 1). When action ceases, add 5 cc. of hydrochloric acid and evaporate to dryness. Add 10 cc. of hydrochloric acid, evaporate to dryness and bake the residue at a moderate temperature. Dissolve the residue in 10 cc. of hydrochloric acid, add 30 cc. of water, boil and filter. Wash the residue with hot dilute hydrochloric acid (1:9) followed by water (Note 2).

Evaporate the solution to dryness on a steam-bath, add 20 cc. of hydrochloric acid and warm gently until complete solution is obtained. Cool the solution in ice water and pass hydrochloric acid gas into it to saturation. Add 20 cc. of ether and continue passing the gas into the cold solution until it is again saturated. Allow the mixture to stand for several hours, keeping it cold by immersing the container in ice water. If the solution becomes warm or if it is not allowed to stand, the separation of hydrated aluminum chloride is not quite complete.

Filter through asbestos (small Bückner-asbestos pad washed once with cold ether - hydrochloric acid mixture immediately before use), wash, by decantation, with a cold mixture of equal parts of strong hydrochloric acid and ether which has been saturated with hydrochloric acid gas. The aluminum chloride retains a little vanadium.

Dissolve the precipitated aluminum chloride in the least possible amount of dilute hydrochloric acid (1:9) back into the original beaker, from which all of the precipitate need not have been removed. Evaporate the solution to near dryness on a steam-bath, add 10 cc. of strong hydrochloric acid and pass hydrochloric acid gas into the solution to saturation, add 15 cc. of ether and continue passing hydrochloric acid gas to saturation, keeping the solution cold by

[1] Gooch-Havens, *Am. Journal of Science*, Vol. 4, pp. 11–416.

means of ice water. Let stand several hours, filter on asbestos and wash with the ether - hydrochloric acid mixture as before.

Dissolve the aluminum chloride in dilute hydrochloric acid (1:9) into a 250-cc. beaker, add a few grams of ammonium chloride, make faintly alkaline with ammonia, boil, filter (using paper pulp), wash with hot water, dry, ignite and weigh as Al_2O_3.

According to published data, this method gives a complete separation of aluminum from iron, beryllum, zinc, copper, mercury and bismuth. A little vanadium is carried down in the first separation, but two chloride precipitations seem to give a practically complete separation. The proportion of vanadium retained in the final alumina is hardly appreciable when working on a 35-per-cent vanadium alloy.

The effect of chromium is not known; presumably some of it would be included in the Al_2O_3. This could be corrected for by fusing the Al_2O_3 with sodium peroxide and estimating the Cr_2O_3 by color.

NOTES

1. Dilute nitric acid (sp. gr. 1.135) is recommended for solution. While this requires rather long digestion at steam-bath temperature, solution seems to be quite complete even when the alloy is high in silicon. In some cases where silicon is very high it is necessary to use a little hydrofluoric acid with the nitric acid. In this case solution should be effected in a platinum dish, the solution evaporated to dryness and the dry residue transferred to a beaker before treatment with hydrochloric acid. A little dilute hydrochloric acid may be used to loosen any oxides that adhere to the dish.

2. The siliceous residue may retain alumina; it should be ignited in platinum. Silica should be expelled by HF + H_2SO_4 and the residue fused with $KHSO_4$. After dissolving the fusion in water plus a little HCl, the liquid is made faintly alkaline with ammonia and boiled. Any iron and alumina precipitate is removed by filtration, washed with water, dissolved in a little hot dilute HCl and added to the solution of the alumina obtained after the first ether - hydrochloric acid separation.

FERRO-TUNGSTEN AND TUNGSTEN METAL

DETERMINATION OF TUNGSTEN

SOLUTIONS REQUIRED

Cinchonine Solution.—Dissolve 125 g. of cinchonine in a mixture of 500 cc. of HCl (sp. gr. 1.19) and 500 cc. of distilled water.

Cinchonine Wash Solution.—Dilute 30 cc. of the above solution to one liter.

Treat 1 g. of the material passing a No. 100 sieve in a large (60-cc.) platinum crucible with 5 cc. of HF; add HNO_3 drop by drop until the metal dissolves. Add 3 to 4 cc. of H_2SO_4 and evaporate on a steam-bath until HNO_3 + HF is expelled. Shake gently over a

small Bunsen flame, or heat slowly in a sheet iron "radiator" (described by Hillebrand)[1] until H_2SO_4 fumes strongly. Cool, transfer to a 250-cc. beaker with water, finally wiping the crucible with a little filter paper. A little WO_3 sticks to the crucible; it can not be removed by wiping. Reverse the crucible. Dilute the contents of the beaker to about 150 cc. with water, add 10 cc. of hydrochloric acid (sp. gr. 1.19) and boil for a few minutes. Remove from the source of heat, add 10 cc. of cinchonine solution and digest the solution at 80 to 90° C. with occasional stirring, for 30 to 45 minutes.

Add some paper pulp to the solution, stir the solution and when the tungsten precipitate has settled, filter on a 9-cm. paper containing a little "ashless" filter pulp. Wash thoroughly with hot cinchonine solution and finally several times with warm 1-per-cent hydrochloric acid. Gently ignite the filter and residue of crude WO_3 in the crucible in which it was originally treated until the carbon is consumed. Add a few drops of nitric acid and dry in the radiator. Ignite the covered crucible for 5 minutes in the full heat of a Bunsen burner, cool, and weigh. Ignitions may be made at about 750° C. in an electric muffle. As WO_3 is slowly but steadily volatilized at temperatures above 750° C., serious error may result from continued ignition of the tungsten trioxide at the temperature that is specified. Add about 5 g. of Na_2CO_3 and fuse, running the fusion around the side of the crucible to remove all WO_3. Dissolve the fusion in hot water, add alchohol, heat, filter and wash with hot water. Place the filter in the crucible and ignite; add a little Na_2CO_3 and fuse again. Dissolve the fusion in water, filter and wash *very* thoroughly with hot water to remove the last traces of Na_2CO_3; ignite in the same crucible as at first, cool, and weigh. The difference between the weight of crucible plus residue and the weight of crucible plus impure tungstic oxide is $WO_3 \times 0.7931 = W$.

NOTES

At the best, direct determination of tungsten in high-grade metal is subject to inherent errors. Accuracy within 0.2 per cent is all that can be expected by any method.

DETERMINATION OF CARBON

See the Determination of Carbon in Ferro-Chromium by the Direct-Combustion Method.[2] The alloy ground to pass a No. 100 sieve and mixed with 2 g. of pure iron is burned in an electric furnace heated at 1050 to 1100° C. A "blank" on the ingot iron must be determined and deducted.

[1] U. S. Geological Survey *Bulletin No. 700*, p. 33.

[2] See p. 500.

DETERMINATION OF PHOSPHORUS

Treat 1 g. of the finely powdered sample in a platinum dish, fitted with a gold cover, with 15 cc. of HNO_3 (sp. gr. 1.42), add 3 cc. of HF and warm gently. When action subsides add 3 cc. more of HF. After action subsides, boil, remove cover and if decomposition is not complete add more HF and boil again. When solution is complete, wash off the cover and evaporate at a low heat to a volume of about 10 cc., then add 3 or 4 drops of concentrated permanganate solution and continue evaporation until crusts of WO_3 begin to form at the edges, that is to a volume of about 6 cc. Add 5 cc. of H_2SO_4 and evaporate on the stove at a low heat until HF and HNO_3 are expelled and H_2SO_4 fumes are given off. (Strong heat causes spattering and also causes hard over-baked crusts to form on the bottom of the dish which resist subsequent treatment.) Cool, add 25 cc. of water and boil (by agitating over a Bunsen flame) until all soluble salts are dissolved. Discharge pink color, due to excess permanganate, by adding sulfurous acid drop by drop. The pink color may not be very evident but the SO_2 is added even so to reduce higher oxides of manganese. Boil for a minute or two after adding the SO_2. Add 1.20 g. of pure tartaric acid and, when this is dissolved and the solution is cooled to a temperature of about 50° C., add 20 cc. of NH_4OH (sp. gr. 0.90) diluted with an equal volume of water. The precipitated tungstic acid should dissolve completely, giving a clear solution. The solution becomes hot from the reaction between H_2SO_4 and NH_4OH. While it is still hot, add 10 cc. of magnesia mixture and transfer it from the platinum dish to a 6-oz. glass-stoppered bottle. Set the bottle in ice water and when it is thoroughly cooled add four or five glass beads about 6 mm. in diameter. Stopper it tightly and shake in an efficient shaking machine for at least ten minutes. The agitation should be violent. The beads aid in starting the formation of the magnesium precipitate; after agitation add 15 cc. of strong NH_4OH and return the bottle to the ice-water tank and put into a refrigerator to stand overnight. Phosphorus separates as magnesium ammonium phosphate free from tungsten but containing possibly basic magnesium compounds. After standing overnight filter the solution through a 9-cm. paper containing a little paper pulp and wash the bottle and paper thoroughly by small additions of ammonia wash water (1 part NH_4OH to 3 parts H_2O). Do not attempt to remove all the precipitate from the bottle but remove the beads to the filter. The precipitate consists of magnesium ammonium phosphate and arsenate together with silica and other impurities. Tin,

tungsten, molybdenum, vanadium and titanium are eliminated by precipitation with magnesia mixture in the presence of tartaric acid. Dissolve the magnesia precipitate in hot dilute HCl and evaporate to a small volume, say 7 or 8 cc. Add 10 cc. of strong HCl and 0.5 g. of KBr and evaporate to dryness. Take up with 5 cc. of HNO_3 and evaporate to dryness again. The KBr serves to reduce As^v to As'''. The addition of strong HCl and boiling followed by evaporation to dryness eliminates As. Dissolve residue in 60 cc. of HNO_3 (sp. gr. 1.135), filter into a 250-cc. shaking bottle; add 40 cc. of NH_4OH (sp. gr. 0.96), cool to 33° C., add 30 cc. of molybdate solution (Blair) and finish the determination by the alkalimetric method (Handy) described in Blair's Chemical Analysis of Iron.

NOTES

The usual proportions of HNO_3 and HF are reversed in order to provide a constant excess of HNO_3 to oxidize P. The procedure given takes a little longer than when the sample is treated with HF first and HNO_3 is added a little at a time, but the solution is finally complete. It is necessary to keep the platinum dish covered after action begins, as the reaction is somewhat violent.

The platinum dishes recommended are:

8 cm. in diameter at top;
7.8 cm. in diameter at bottom;
4 cm. high.

They have flat bottoms and are wire-rimmed at the top to give additional stiffness. They weigh 58 to 60 g. each and hold about 175 cc. The covers are made of pure gold (for economy), "dished" like a crucible cover to fit the top of the dishes closely. The dishes have small lips to aid pouring. The "tongue" of the cover overlaps the lip. Ordinary round-bottomed dishes may be used, but the manipulation is much more difficult; there is a greater tendency to spattering and danger of local baking or overheating in evaporating to fumes of H_2SO_4. If the separated WO_3 is overheated locally it does not dissolve readily in NH_4OH. In flat-bottomed dishes, the WO_3 is spread in a thin layer and heat is applied evenly all over the bottom.

A good shaking machine should be used. The magnesia precipitate may be started by shaking the bottles by hand, but it is a tiresome job. The solution must be cold, say 8 or 10° C., when shaking begins.

Permanganate solution is added to insure complete oxidation of phosphorus, as in steel analysis. The color of the permanganate gradually fades in the hydrofluoric nitric solution, but after evaporating to fumes and adding water the solution is usually slightly pink.

The amount of tartaric acid is limited to 1.20 g. since ammonium tartrate retards the formation of the magnesia precipitate. Complete precipitation can only be obtained by brisk agitation and by keeping the solution very cold, followed by long standing in a cold place. By this method determinations started at 3 p. m. may be completed by noon the next day.

DETERMINATION OF SULFUR AND SILICON

SOLUTIONS REQUIRED

Cinchonine Solution.—Thoroughly wash cinchonine reagent with hot water on a Büchner funnel, dry, and dissolve 125 g. of the washed cinchonine in a mixture of 500 cc. of HCl (sp. gr. 1.19) and 500 cc. of distilled water.

Cinchonine Wash Solution.—Dilute 30 cc. of the above solution to one liter.

Barium Chloride Solution.—One hundred grams of $BaCl_2 \cdot 2H_2O$ to 1000 cc.

SULFUR

Fuse 2 g. of the finely powdered metal, intimately mixed with 8 g. of dry Na_2CO_3 and 2 g. of powdered KNO_3, in a large platinum crucible (40 cc.). The fusion is best done over an alcohol blast flame or in an electric muffle to avoid contamination with sulfur contained in illuminating gas. Leach the fusion with 100 cc. of distilled water in a 250-cc. beaker. Filter into a 12-cm. porcelain casserole and wash the residue several times with hot distilled water. The solution contains practically all of the sulfur and most of the tungsten and silica. The residue contains some of each, but not more than traces of sulfur.

Render the liquid acid with 20 cc. of HCl and evaporate to dryness on a steam-bath, thus precipitating tungstic acid. After the residue is dry, heat it to 110 to 120° C. in an oven to dehydrate silica, take up with 5 cc. of HCl and 50 cc. of water, add 3 cc. of a strong cinchonine solution and boil, or heat just short of the boiling point, for 30 minutes. Let the solution stand for at least three hours and preferably overnight. By means of the cinchonine, all WO_3 is rendered insoluble. Filter through an 11-cm. filter paper (free from ash) which has been liberally treated with an emulsion of filter paper pulp and wash the residue with dilute cinchonine solution. Reserve the residue. The filtrate contains all the sulfur; heat it to boiling and add 10 cc. of barium chloride solution, boil for ten minutes, allow it to stand overnight, filter on a 9-cm. filter paper (free from ash), wash repeatedly but not excessively with hot water, ignite in platinum and weigh as $BaSO_4$. If the work is properly carried out every trace of WO_3 is removed from the solutions and there is no danger of including $BaWO_4$ with the $BaSO_4$. If one suspects that the $BaSO_4$ is not quite pure, it should be fused with a little Na_2CO_3, leached with water and filtered; the filtrate should be acidulated with HCl, a few drops of cinchonine solution added and the solution evaporated to dryness on a steam-bath. The dry residue should be dissolved in a little water,

a few drops of HCl added, and any residue filtered off. In the clear filtrate $BaSO_4$ should be again precipitated as before. The weight of $BaSO_4 \times 0.1374 = S$.

"Blanks" on all reagents must be made parallel with the determination; this is important since all sodium carbonate obtainable contains sulfur and there is sometimes more or less of it in cinchonine. All evaporations should be made over steam and the operations conducted in a place free from sulfur gases.

NOTE

Evolution of sulfur in a stream of hydrogen saturated with hydrochloric acid as in Johnson's Method is optional.

SILICON

The residue of tungstic oxide from which the solution for the determination of sulfur was filtered contains most of the silica. The residue from leaching the original fusion contains the rest.

Wash the residue from Na_2CO_3 fusion from the filter paper with a fine jet of water into a small casserole, add an excess of HCl and evaporate to dryness on a steam-bath, heat the dry residue at 110 to 120° C. to dehydrate the silica, drench with hydrochloric acid, dilute to 100 cc. with hot water, heat until salts are in solution, and filter on a small filter paper (free from ash). Wash thoroughly with hot dilute HCl (1:100) and finally with hot water. Reserve the filter.

Wash the residue of tungstic oxide, silica and filter paper pulp from the filter into a small casserole, add 5 cc. of HCl and heat for a few minutes, then filter again through the same paper and wash it *thoroughly* with hot water. This second washing is necessary to remove sodium salts completely. (The original washing sufficed to remove all of the small amount of sulfur present.) Transfer the well-washed filter and residue to a platinum crucible, add the small filter containing the little silica recovered from the Na_2CO_3 fusion residue and ignite both to constant weight in a platinum crucible. On account of the presence of filter paper pulp, the ignited residue is porous and friable; if paper pulp had not been used the WO_3 would be dense and not easily susceptible to the subsequent treatment. Cool the ignited residue of WO_3 and SiO_2 and weigh it. Add 2 or 3 drops of H_2SO_4 and 5 or 6 cc. of pure HF. Digest at a gentle heat for some time, and then slowly evaporate off the HF. When H_2SO_4 fumes are evolved, cool and again add HF, digest as before, evaporate off the HF, ignite gently to expel H_2SO_4 and heat strongly for ten or fifteen minutes. Cool and weigh. The loss in weight after expulsion is SiO_2 which multiplied by 0.4672 equals silicon.

STANDARD SPECIFICATIONS

FOR

LAKE COPPER WIRE BARS, CAKES, SLABS, BILLETS, INGOTS, AND INGOT BARS[1]

Serial Designation: B 4 – 27

These specifications are issued under the fixed designation B 4; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ADOPTED, 1911; REVISED, 1913, 1927.

Definition. 1. In order to be classed as Lake, copper must originate on the northern peninsula of Michigan, U. S. A.

Marks. 2. All wire bars, cakes, slabs, and billets shall be stamped with the maker's brand and furnace charge mark. Ingots and ingot bars shall have a brand stamped or cast in, but need have no furnace charge mark.

Lots. 3. The refiner shall arrange carloads or lots so that as far as possible each shall contain pieces from but one furnace charge, in order to facilitate testing by the user.

Resistivity. 4. (*a*) *Low Resistance Lake.*—Lake copper offered for electrical purposes, whether fire or electrolytically refined, shall be known as "Low Resistance Lake."

Low Resistance Lake wire bars shall have a resistivity not to exceed 0.15436 international ohms per meter-gram at 20° C. (annealed). All ingots and ingot bars shall have a resistivity not to exceed 0.15694 international ohms per meter-gram at 20° C. (annealed).

Cakes, slabs, and billets shall come under the ingot classification, except when specified for electrical use at time of purchase; in which case wire-bar classification shall apply.

(*b*) *High Resistance Lake.*—Lake copper having a resistivity greater than 0.15694 international ohms per meter-gram at 20° C. shall be known as "High Resistance Lake."

Metal Content. 5. (*a*) Low Resistance Lake copper shall have a purity of at least 99.900 per cent as determined by electrolytic assay, silver being counted as copper.

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee B-2 on Non-Ferrous Metals and Alloys.

(*b*) High Resistance Lake copper shall have a purity of at least 99.900 per cent, copper, silver, and arsenic being counted together. The arsenic content of High Resistance Lake copper, when required for special purposes, shall be the subject of agreement at time of purchase.

Physical Standard.

6. Wire bars, cakes, slabs, and billets shall be substantially free from shrink holes, cold sets, pits, sloppy edges, concave tops and similar defects in set or casting. This clause shall not apply to ingots or ingot bars, in which case physical defects are of no consequence.

Standard Sizes and Shapes for 200 to 300-lb. Wire Bars.

7. (*a*) One mold shall be used for casting 200 to 230-lb. wire bars, the bottom width of this bar to be $3\frac{1}{2}$ in., the listed weights being 200 and 225 lb. (See Fig. 1.)

(*b*) One mold shall be used for casting 240 to 300-lb. wire bars, the bottom width of this bar to be 4 in., the listed weights being 250, 275 and 300 lb. (See Fig. 2.)

(*c*) The length dimension of all bars shall be 54 in. The side draft or taper shall be $\frac{3}{8}$ in. in 4 in. ($\frac{3}{16}$ in. in 4 in. on each side of the bar). The radius of the corners at the bottom of the bars shall be $\frac{5}{8}$ in. The end taper at the bottom shall be 6 in. long overall and approximately 2 in. per ft.

The end taper of the side shall be approximately $2\frac{1}{4}$ in. per ft. and the end of the bar shall be approximately $3\frac{3}{8}$ in. deep at the point.

Weights of Individual Pieces.

8. Five per cent variation in weight or $\frac{1}{4}$ in. variation in any dimension from the refiner's published list or purchaser's specified size shall be considered good delivery; provided, however, that wire bars may vary in length 1 per cent from the listed or specified length, and cakes 3 per cent from the listed or specified size in any dimension greater than 8 in. The weight of ingot and ingot-bar copper shall not exceed that specified by more than 10 per cent, but otherwise its variation is not important.

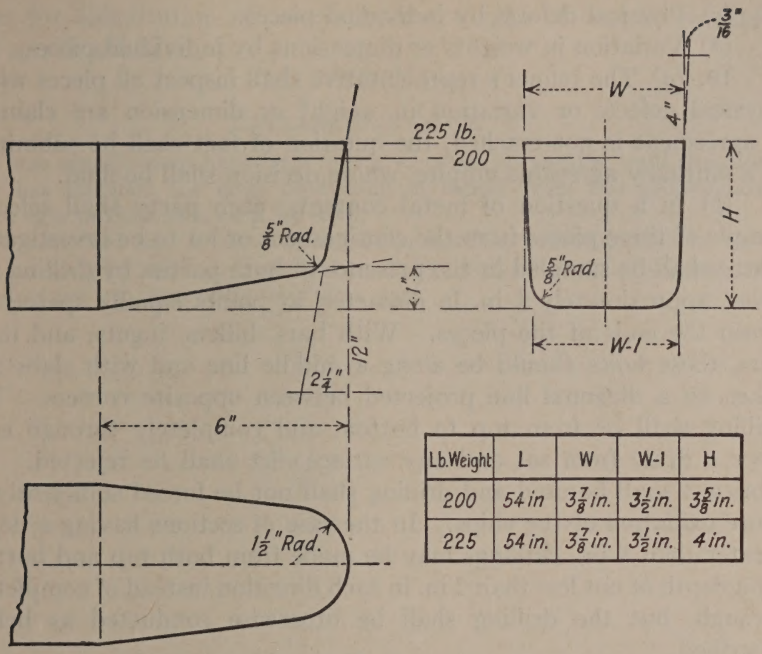
Claims.

9. Claims shall be made in writing within thirty days of receipt of copper at the customer's mill, and the results of the customer's test shall accompany such claims. The refiner shall be given one week from date of receipt of complaint to investigate his records, and shall then either agree to replace the defective copper or send a representative to the mill. No claims will be considered unless made as above stated, and if the copper in question, unused, cannot be shown to the refiner's representative.

Claims against quality will be considered as follows:

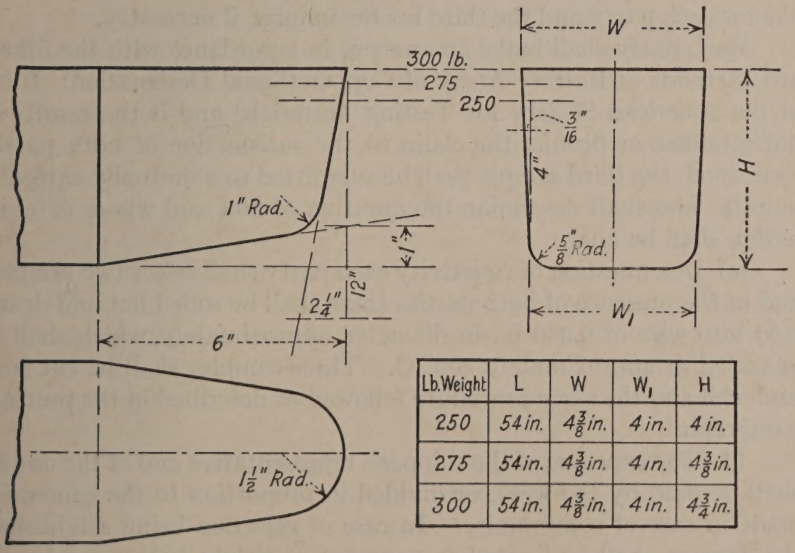
(*a*) Resistivity by furnace charges, ingot lots, or ingot-bar lots.

(*b*) Metal contents by furnace charges, ingot lots, or ingot-bar lots.



Lb. Weight	L	W	W-1	H
200	54 in	3 7/8 in.	3 1/2 in.	3 5/8 in.
225	54 in.	3 7/8 in.	3 1/2 in.	4 in.

FIG. 1.



Lb. Weight	L	W	W_1	H
250	54 in.	4 3/8 in.	4 in.	4 in.
275	54 in.	4 3/8 in.	4 in.	4 3/8 in.
300	54 in.	4 3/8 in.	4 in.	4 3/4 in.

FIG 2.

(*c*) Physical defects by individual pieces.

(*d*) Variation in weights or dimensions by individual pieces.

Investigation of Claims.

10. (*a*) The refiner's representative shall inspect all pieces where physical defects or variation in weight or dimension are claimed. If agreement is not reached, the question of fact shall be submitted to a mutually agreeable umpire, whose decision shall be final.

(*b*) In a question of metal contents, each party shall select a sample of three pieces from the consignment or lot to be investigated. These shall be sampled in the presence of both parties by drilling five holes, approximately $\frac{1}{2}$ in. in diameter, at points equally spaced between the ends of the pieces. With bars, billets, ingots, and ingot bars, these holes should be along a middle line and with slabs and cakes on a diagonal line projected between opposite corners. The drilling shall be from top to bottom and completely through each piece. Scale from set and any surface dirt shall be rejected. No lubricant shall be used and drilling shall not be forced sufficiently to cause oxidation of the chips. In the case of sections having a depth greater than 5 in., drillings may be made from both top and bottom for a depth of not less than 2 in. in each direction instead of completely through, but the drilling shall be otherwise conducted as before described.

The resulting sample shall be cut up, mixed and separated into three equal portions, each of which shall be placed in a sealed package, one for each party and the third for the umpire, if necessary.

Each party shall make an analysis in accordance with the Standard Methods of Battery Assay of Copper (Serial Designation: B 34) of the American Society for Testing Materials[1] and if the results do not establish or dismiss the claim to the satisfaction of both parties concerned, the third sample shall be submitted to a mutually agreeable umpire, who shall determine the question of fact and whose determination shall be final.

(*c*) In a question of resistivity each party shall select two samples, and in the presence of both parties these shall be rolled hot and drawn cold into wire of 0.080 in. in diameter, approximately, which shall be annealed at approximately 500° C. Three samples shall be cut from each coil and the same procedure followed as described in the previous paragraph.

Settlement of Claims.

11. The expenses of the shipper's representative and of the umpire shall be paid by the loser, or divided in proportion to the concession made in case of compromise. In case of rejection being established, the damage shall be limited to payment of freight both ways by the

[1] See p. 663.

refiner for substitution of an equivalent weight of copper meeting these specifications.

EXPLANATORY NOTE

These specifications have been drawn to cover the peculiar trade situation which has classified the large production of copper from this geographical district as a product in a class by itself.

It is realized that a better classification from an academic point of view could be made by method of production or by chemical composition, but the trade does not yet seem ready for such a step.

STANDARD SPECIFICATIONS
FOR
ELECTROLYTIC COPPER WIRE BARS, CAKES, SLABS, BILLETS, INGOTS, AND INGOT BARS[1]

Serial Designation: B 5 – 27

These specifications are issued under the fixed designation B 5; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ADOPTED, 1911; REVISED, 1913, 1927.

Marks. 1. All wire bars, cakes, slabs, and billets shall be stamped with the maker's brand and furnace charge mark. Ingots and ingot bars shall have a brand stamped or cast in, but need have no furnace charge mark.

Lots. 2. The refiner shall arrange carloads or lots so that as far as possible each shall contain pieces from but one furnace charge, in order to facilitate testing by the user.

Quality. 3. (*a*) *Metal Content.*—The copper in all shapes shall have a purity of at least 99.900 per cent, as determined in accordance with the Standard Methods of Battery Assay of Copper (Serial Designation: B 34) of the American Society for Testing Materials,[2] silver being counted as copper.

(*b*) *Resistivity.*—All wire bars shall have a resistivity not to exceed 0.15436 international ohms per meter-gram at 20° C. (annealed); all ingots and ingot bars shall have a resistivity not to exceed 0.15694 international ohms per meter-gram at 20° C. (annealed).

Cakes, slabs, and billets shall come under the ingot classification, except when specified for electrical use at time of purchase, in which case wire-bar classification shall apply.

Physical Standard. 4. Wire bars, cakes, slabs, and billets shall be substantially free from shrink holes, cold sets, pits, sloppy edges, concave tops, and similar defects in set or casting. This clause shall not apply to ingots or ingot bars, in which case physical defects are of no consequence.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M Committee B-2 on Non-Ferrous Metals and Alloys.

[2] See p. 663.

Weights of Individual Pieces.

5. Five per cent variation in weight or $\frac{1}{4}$ in. variation in any dimension from the refiner's published list or purchaser's specified size shall be considered good delivery; provided, however, that wire bars may vary in length 1 per cent from the listed or specified length, and cakes 3 per cent from the listed or specified size in any dimension greater than 8 in. The weight of ingot and ingot-bar copper shall not exceed that specified by more than 10 per cent, but otherwise its variation is not important.

Standard Sizes and Shapes for 200 to 300-lb. Wire Bars.

6. (*a*) One mold shall be used for casting 200 to 230-lb. wire bars, the bottom width of this bar to be $3\frac{1}{2}$ in., the listed weights being 200 and 225 lb. (See Fig. 1.)

(*b*) One mold shall be used for casting 240 to 300-lb. wire bars, the bottom width of this bar to be 4 in., the listed weights being 250, 275 and 300 lb. (See Fig. 2.)

(*c*) The length dimension of all bars shall be 54 in. The side draft or taper shall be $\frac{3}{8}$ in. in 4 in. ($\frac{3}{16}$ in. in 4 in. on each side of the bar). The radius of the corners at the bottom of the bars shall be $\frac{5}{8}$ in. The end taper at the bottom shall be 6 in. long overall and approximately 2 in. per ft.

The end taper of the side shall be approximately $2\frac{1}{4}$ in. per ft. and the end of the bar shall be approximately $3\frac{3}{8}$ in. deep at the point.

Claims.

7. Claims shall be made in writing within thirty days of receipt of copper at the customer's mill, and the results of the customer's tests shall accompany such claims. The refiner shall be given one week from date of receipt of complaint to investigate his records, and shall then either agree to replace the defective copper or send a representative to the mill. No claims shall be considered unless made as above stated, and if the copper in question, unused, cannot be shown to the refiner's representative.

Claims against quality will be considered as follows:

(*a*) Resistivity by furnace charges, ingot lots, or ingot-bar lots.

(*b*) Metal contents by furnace charges, ingot lots, or ingot-bar lots.

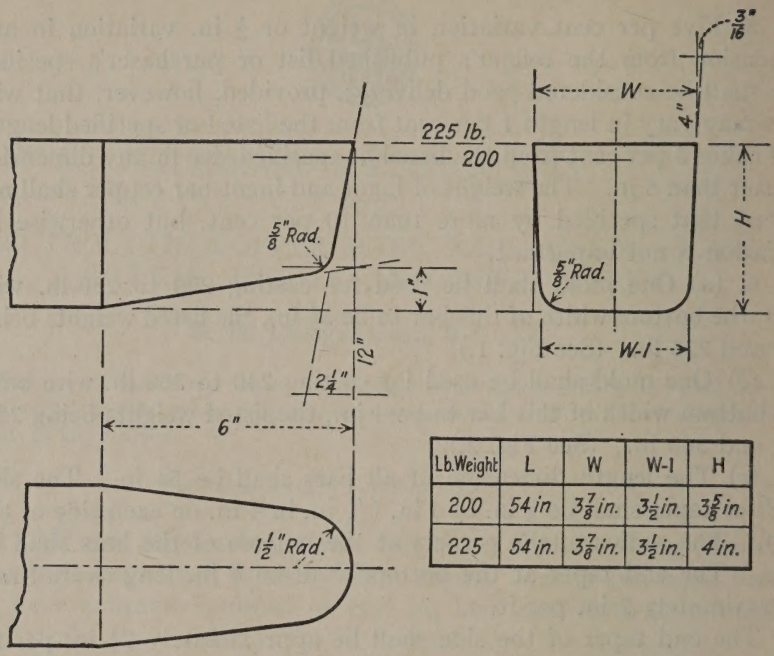
(*c*) Physical defects by individual pieces.

(*d*) Variation in weights or dimensions by individual pieces.

Investigation of Claims.

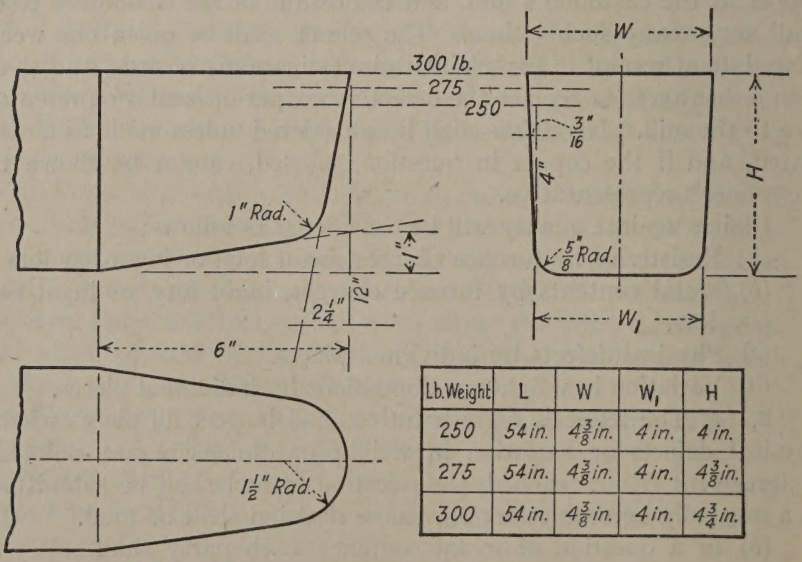
8. (*a*) The refiner's representative shall inspect all pieces where physical defects or variation in weight or dimension are claimed. If agreement is not reached, the question of fact shall be submitted to a mutually agreeable umpire, whose decision shall be final.

(*b*) In a question of metal contents, each party shall select a sample of three pieces from the consignment or lot to be investigated. These shall be sampled in the presence of both parties by drilling five



Lb. Weight	L	W	W-1	H
200	54 in	3 7/8 in.	3 1/2 in.	3 5/8 in.
225	54 in.	3 7/8 in.	3 1/2 in.	4 in.

FIG. 1.



Lb. Weight	L	W	W_1	H
250	54 in.	4 3/8 in.	4 in.	4 in.
275	54 in.	4 3/8 in.	4 in.	4 3/8 in.
300	54 in.	4 3/8 in.	4 in.	4 3/4 in.

FIG. 2.

holes approximately ½ in. in diameter, at points equally spaced between the ends of the pieces. With bars, billets, ingots, and ingot bars, these holes should be along a middle line and with slabs and cakes on a diagonal line projected between opposite corners. The drilling shall be from top to bottom and completely through each piece. Scale from set and any surface dirt shall be rejected. No lubricant shall be used and drilling shall not be forced sufficiently to cause oxidation of the chips. In the case of sections having a depth greater than 5 in., drillings may be made from both top and bottom for a depth of not less than 2 in. in each direction instead of completely through, but the drilling shall be otherwise conducted as before described.

The resulting sample shall be cut up, mixed and separated into three equal portions, each of which shall be placed in a sealed package, one for each party and the third for the umpire, if necessary.

Each party shall make an analysis and if the results do not establish or dismiss the claim to the satisfaction of both parties concerned, the third sample shall be submitted to a mutually agreeable umpire, who shall determine the question of fact and whose determination shall be final.

(*c*) In a question of resistivity each party shall select two samples, and in the presence of both parties these shall be rolled hot and drawn cold into wire of 0.080 in. in diameter, approximately, which shall be annealed at approximately 500° C. Three samples shall be cut from each coil and the same procedure followed as described in the previous paragraph.

Settlement of Claims.

9. The expenses of the shipper's representative and of the umpire shall be paid by the loser, or divided in proportion to the concession made in case of compromise. In case of rejection being established, the damage shall be limited to payment of freight both ways by the refiner for substitution of an equivalent weight of copper meeting these specifications.

STANDARD SPECIFICATIONS

FOR

SPELTER[1]

Serial Designation: B 6 – 18

These specifications are issued under the fixed designation B 6; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ADOPTED, 1911; REVISED, 1914, 1918.

Scope.

1. Under these specifications Virgin Spelter, that is, spelter made from ore or similar raw material by a process of reduction and distillation or by electrolysis and not produced from reworked metal, is considered in five grades, as follows:

(1).....High Grade.
(2).....Intermediate.
(3).....Brass Special.
(4).....Selected.
(5).....Prime Western.

Marks.

2. A brand shall be cast in each slab by which the maker and grade can be identified.

Quality.

3. The maker shall use care to have each carload of as uniform quality as possible.

Composition.

4. (*1*) *High Grade.*[2]—The spelter shall not contain over:

0.07 per cent lead.
0.03 " iron.
0.07 " cadmium.

It shall be free from aluminum.

The sum of the lead, iron, and cadmium shall not exceed 0.10 per cent.

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee B-2 on Non-Ferrous Metals and Alloys.

[2] For slush castings and certain zinc-aluminum alloys, a special grade of spelter may be required, as noted in "Spelter, Its Grades and Uses," published as Appendix I to the report of Committee B-2 on Non-Ferrous Metals and Alloys, *Proceedings*, Am. Soc. Testing Mats., Vol. XVI, Part I, p. 183 (1916).

(*2*) *Intermediate.*—The spelter shall not contain over:

0.20 per cent lead.
0.03 " iron.
0.50 " cadmium.

It shall be free from aluminum.

The sum of the lead, iron, and cadmium shall not exceed 0.50 per cent.

(*3*) *Brass Special.*—The spelter shall not contain over:

0.60 per cent lead.
0.03 " iron.
0.50 " cadmium.

It shall be free from aluminum.

The sum of the lead, iron, and cadmium shall not exceed 1.0 per cent.

(*4*) *Selected.*—The spelter shall not contain over:

0.80 per cent lead.
0.04 " iron.
0.75 " cadmium.

It shall be free from aluminum.

The sum of the lead, iron, and cadmium shall not exceed 1.25 per cent.

(*5*) *Prime Western.*—The spelter shall not contain over:

1.60 per cent lead.
0.08 " iron.

Physical. 5. The slabs shall be reasonably free from surface corrosion or adhering foreign matter.

Sampling. 6. Take ten slabs[1] at random from a carload and saw each slab completely across from the middle of one long side to the middle of the other and use the sawdust as the sample; or, drill three 9-mm. holes along one diagonal of each slab, boring completely through and taking care to make fine drillings; the holes should be drilled as nearly as possible at the middle and halfway between either end and the middle of such diagonals. Go over the drillings or sawings with a powerful magnet to

[1] Section 6 on Sampling is based on the Report of the Sub-Committee on Methods of Analysis of Non-Ferrous Alloys of the Division of Industrial Chemists and Chemical Engineers of the American Chemical Society, approved by the Supervisory Committee on Standard Methods of Analysis of that Society; *Journal of Industrial and Engineering Chemistry*, Vol. 7, p. 547, 1915.

take out any iron which may have come from the drill or saw, and mix the sample thoroughly. The drill or saw shall be thoroughly cleaned before use, and no lubricant shall be used in either drilling or sawing.

Claims.

7. Claims to be considered shall be in writing within thirty days of receipt of material at customer's plant and the results of customer's test shall be given. The shipper shall be given one week from date of receipt of such claim to investigate his records and then shall either agree to satisfy the claim or send a representative to the plant.

(*a*) *Analysis by Car Lots.*—No claims shall be considered unless the minimum samples as specified for the grade in question can be shown to such representative.

(*b*) *Physical Defects of Individual Pieces.*—No claims shall be considered unless the spelter in question, unused, can be shown to such representative.

Plant Treatment.

8. Where the spelter satisfies the chemical and physical requirements of these specifications, it shall not be condemned for defects of alloys in which it is used or for defects in the coating of galvanized products.

Investigation of Claims.

9. The maker's representative shall inspect all pieces where physical defects are claimed. If agreement is not reached the question of fact shall be submitted to a mutually agreeable umpire, whose decision shall be final.

On a question of metal contents a sample shall be drawn by representatives of both parties as described under "Sampling," Section 6. The properly mixed and quartered sample shall be separated into three parts, each of which shall be placed in a sealed package, one for each party and one for an umpire if necessary. Each part shall make an analysis, and if the results do not establish or dismiss the claim to the satisfaction of both parties, the third sample shall be submitted to a mutually agreeable umpire, who shall determine the question of quality, and whose determination shall be final.

Settlement of Claims.

10. The expenses of the seller's representative and of the umpire shall be paid by the loser or divided in proportion to concession made in case of compromise.

In case of rejection being established, damages shall be limited to the payment of freight both ways by the seller for substitution of an equivalent weight of spelter meeting these specifications.

STANDARD SPECIFICATIONS
FOR
PIG LEAD[1]

Serial Designation: B 29 – 23

These specifications are issued under the fixed designation B 29; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1919; ADOPTED IN AMENDED FORM, 1923.

Scope. 1. These specifications are intended to cover lead in pig form, made from ore or similar raw materials, by processes of reduction and refining, and not produced from reworked material.

Grades. 2. Under these specifications pig lead is considered in three grades, as follows:

Grade I. Corroding Lead.
Grade II. Chemical Lead.
Grade III. Common Lead.

MANUFACTURE

Quality. 3. The maker shall use care to have each carload of as uniform quality as possible.

CHEMICAL PROPERTIES AND TESTS

(*A*) *Chemical Composition.*

Corroding Lead. 4. Corroding Lead (Grade I) shall conform to the following requirements as to chemical composition:

Silver	not over	0.0015	per cent.
Copper	" "	0.0015	"
Copper and silver together	" "	0.0025	"
Arsenic	" "	0.0015	"
Antimony and Tin together	" "	0.0095	"
Zinc	" "	0.0015	"
Iron	" "	0.002	"
Bismuth	" "	0.05	"
Lead (by difference)		99.9330	"

NOTE.—The maximum limits for bismuth, copper and silver have been given, but it is not expected that any delivery will contain the maxmium of all three.

Chemical Lead. 5. Chemical Lead (Grade II) is a designation that has been used for many years in the trade to describe the undesilverized lead produced from Southeastern Missouri ores. This lead contains from 0.04 to 0.08 per cent of copper, from 0.005 to 0.015

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee B-2 on Non-Ferrous Metals and Alloys.

per cent ($1\frac{1}{2}$ to $4\frac{1}{2}$ oz. per ton) of silver and carries less than 0.005 per cent of bismuth.

Common Lead. 6. Common Lead (Grade III) shall conform to the following requirements as to chemical composition:

(*a*) *Desilverized Lead:*

Silver	not over		0.002	per cent.
Copper	"	"	0.0025	"
Arsenic, Antimony and Tin together	"	"	0.015	"
Bismuth	"	"	0.25	"
Iron	"	"	0.002	"
Zinc	"	"	0.002	"
Lead (by difference)			99.7265	"

(*b*) *Soft Missouri Lead:*[1]

Silver	not over		0.002	per cent.
Copper	"	"	0.04	"
Arsenic, Antimony and Tin together	"	"	0.015	"
Bismuth	"	"	0.005	"
Iron	"	"	0.005	"
Zinc	"	"	0.002	"
Lead (by difference)			99.931	"

(*B*) *Sampling and Analysis.*

Sampling. 7. (*a*) In sampling, a carload or less shall be considered a lot or unit. One pig shall be taken to represent each ton of lead in the lot. The pigs thus taken shall be sampled by one of the following methods:

(1) By sawing completely through, as illustrated in Fig. 1;

(2) By punching completely through (if equipment permits) or punching half-way through from two opposite sides, as illustrated in Figs. 2 and 3;

(3) By drilling at least half-way through.

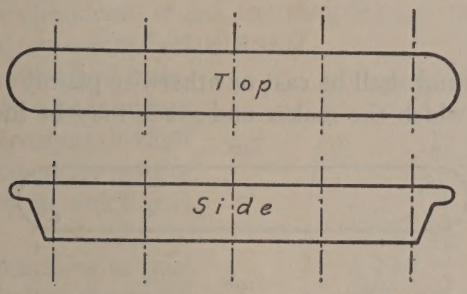
(*b*) Whenever the surface of the pigs to be sampled is dirty, care shall be taken to see that none of the dirt or foreign material gets into the sample.

Sawing. 8. If the sample is taken by sawing, the sawdust from all the pigs shall be thoroughly mixed and quartered and the sample for analysis drawn from the mixed material. Care shall be taken that the sawdust is free from all extraneous material.

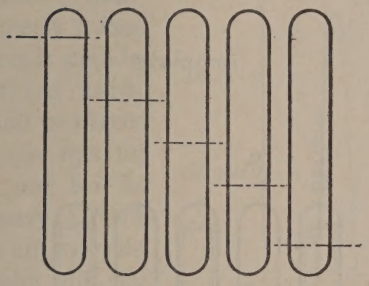
Punching or Drilling. 9. If the sample is taken by punching or drilling, the holes shall be spaced along a diagonal line from one corner of the pig to the other. Sampling in this manner may be so arranged that one or more holes are made in each of several pigs of a group in such positions that they represent consecutive positions on the diagonal of a single pig. (See illustration in Fig. 2.)

[1] Soft Missouri Lead is a trade name used to cover soft undesilverized lead.

(*a*) If punchings are taken, they may be carefully melted in a clean graphite crucible, and either granulated by carefully pouring into distilled water and thoroughly drying, or casting



Template.



The Bars are Sampled in Sets of Five According to Template as Shown above.

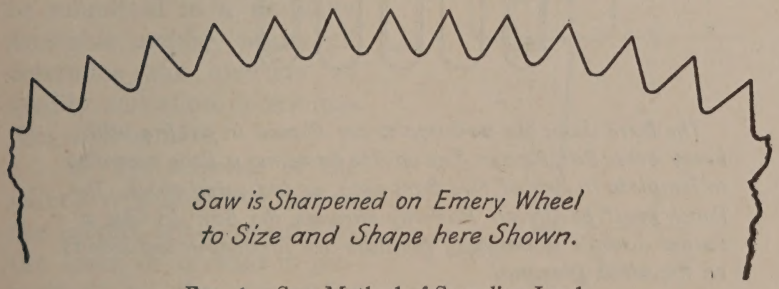


FIG. 1.—Saw Method of Sampling Lead.

into thin slabs which shall be sawed completely through in several places and the sawdust treated as described in Section 8.

(*b*) If drillings are taken, they may be clipped and mixed, and the sample for analysis drawn from the mixed material; or they may be melted as in the case of punchings.

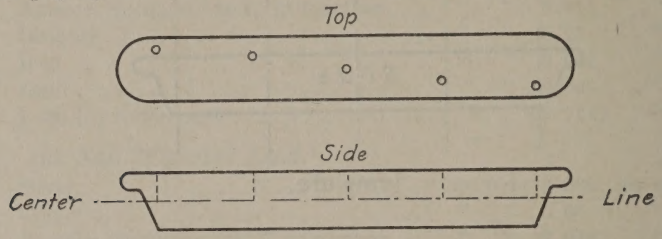
Methods of Chemical Analysis.

10. The chemical analysis shall be made in accordance with the Standard Methods of Chemical Analysis of Pig Lead (Serial Designation: B 35) of the American Society for Testing Materials.[1]

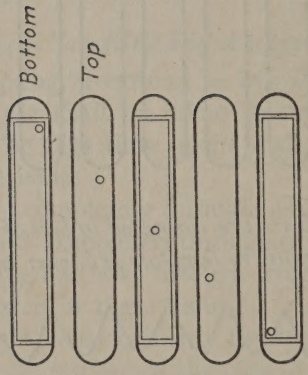
MARKING

Marking.

11. A brand shall be cast or otherwise plainly marked upon each pig by which the maker and grade may be identified.



Template.



The Bars Selected as Samples are Placed in a Line with every other Bar, Bottom Side up. The Sampling is Done according to Template in Sets of five Bars each, as Indicated above. The Punch must be Driven Halfway through the Bar. In Case a Larger Sample is Desired, the Bars are Turned over and Sampled on the other Diagonal.

FIG. 2.—Punch Method of Sampling Lead.

CLAIMS

Claims.

12. (*a*) Claims, to be considered, shall be made in writing within 30 days of receipt of the material at the purchaser's plant, and the results of the purchaser's tests shall be given. The seller

[1] See p. 669.

shall be given one week from date of receipt of such claim to investigate his records, and then shall agree either to satisfy the claim or to the submission of samples to an umpire. No claim shall be considered unless the sample pigs can be shown to the seller's representative.

(*b*) Where the lead satisfies the purity requirements of these specifications, it shall not be condemned for defects in the products in which it is used.

13. On questions of purity a sample shall be drawn by representatives of both parties, as described under "Sampling." The properly mixed and quartered sample shall be separated into three parts, each of which shall be placed in a sealed package, one for each party and one for an umpire, if necessary. Each party shall make an analysis, and if the results do not establish or dismiss the claim to the satisfaction of both parties, the third sample shall be submitted to a mutually agreeable umpire, who shall determine the question of quality, and whose determination shall be final.

14. The expense of the seller's representative and of the umpire shall be paid by the loser, or divided in proportion to the concession made in case of compromise. In case of rejection being established, damages shall be limited to the payment of freight both ways by the seller for substitution of an equivalent weight of lead meeting these specifications.

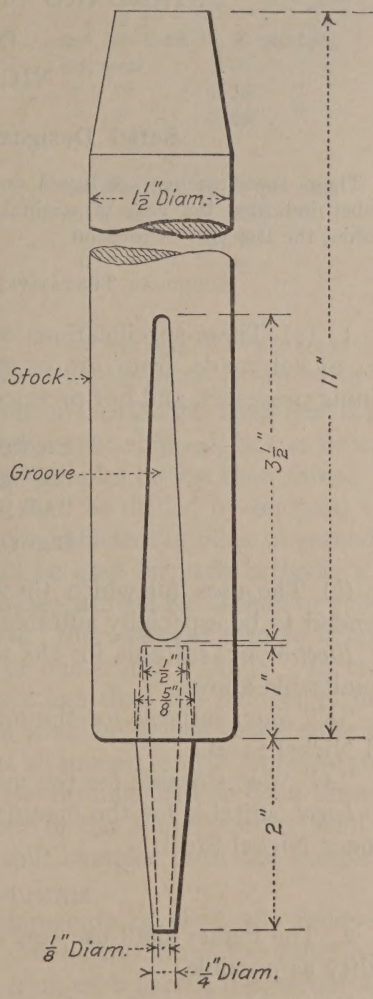


FIG. 3.—Sample Punch for Lead.

Investigation of Claims.

Settlement of Claims.

STANDARD SPECIFICATIONS
FOR
NICKEL[1]

Serial Designation: B 39 – 22

These specifications are issued under the fixed designation B 39; the final number indicates the year of original adoption as standard or, in the case of revision, the last year of revision.

ISSUED AS TENTATIVE, 1921; ADOPTED, 1922.

Scope.

1. (*a*) These specifications cover four grades of Virgin Nickel, *i. e.*, nickel made from ore or matte, or similar raw material by refining processes, and not produced from remelted metal, as follows:

Electrolytic;
"X" Shot;
"A" Shot;
Ingot.

(*b*) The uses for which these four grades of Virgin Nickel are intended to be especially suitable are as follows:

Electrolytic, suitable for the manufacture of the highest grades of malleable alloys.

"X" Shot, suitable for the manufacture of Non-Ferrous Alloys and Nickel Steel.

"A" Shot, suitable for the manufacture of anodes.

Ingot, suitable for the manufacture of open-hearth and electric-furnace Nickel Steel.

MANUFACTURE

Quality.

2. The maker shall use care to have each carload of as uniform quality as possible.

CHEMICAL REQUIREMENTS AND TESTS

Chemical Composition.

3. The nickel shall conform to the following chemical requirements:

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee B-2 on Non-Ferrous Metals and Alloys.

(*a*) *Electrolytic:*

Nickel (including cobalt)	not less than	99.50	per cent
Sulfur	" over	0.02	"
Carbon[1]	" "	0.10	"
Iron	" "	0.25	"

(*b*) *"X" Shot:*

Nickel (including cobalt)	not less than	98.90	per cent
Sulfur	not over	0.05	"
Carbon	" "	0.25	"
Iron	" "	0.60	"

(*c*) *"A" Shot*

Nickel (including cobalt)	not less than	97.75	per cent
Sulfur	not over	0.070	"
Carbon	" "	0.75	"
Iron	" "	0.90	"

(*d*) *Ingot:*

Nickel (including cobalt) ..... not less than 98.50 per cent

It shall be reasonably free from surface corrosion and adhering foreign matter.

Sampling.

4. (*a*) *Electrolytic.*[1]—In all shipments cathodes shall be taken representing five per cent of the total weight shipped, but in no case shall the number of cathodes taken as samples be less than three.

The cathodes taken as samples shall be drilled by templet. In the case of a shipment represented by a sufficient number of cathodes, one line of holes on the templet shall be used for each cathode, *i. e.*, cathode No. 1 shall be drilled at the base, cathode No. 2 shall be drilled with one line of holes further up, etc., the resultant sample being a representation of the total sample of one whole cathode. In cases where the cathodes in the sample are less than the number of lines of holes in the templet, the sample shall be drilled using sufficient lines and fractions thereof to insure at all times a sample representative of one whole cathode. In all cases the drilling shall be done through the cathodes. The drillings obtained in the above manner shall be thoroughly mixed and divided by split sampler until the sample is about 100 g.

(*b*) *"X" Shot.*—In receiving shipments of shot, the following method of sampling shall govern: All barrels from the same melt shall be opened and a sample taken from each barrel, top, center and bottom. These barrel samples shall be mixed, quartered down to 8 oz. and broken into small pieces. This broken sample shall then be quartered down to 100 g., only material passing through a No. 20 sieve being used.

[1] The requirement for carbon in electrolytic nickel covers both contained and mechanically attached carbon from the starting sheet and it should be recognized that while lower values can be btained by separating the cathode sheets from the starting sheet and pickling before drilling, this ethod of taking the sample is outside of these specifications.

(*c*) *"A" Shot.*—The sample shall be taken as described in Paragraph (*b*).

(*d*) *Ingot.*—Ingot nickel shall be sampled according to carloads whenever possible. From each carload fifty ingots shall be taken at random. In case of less than carload shipments, 5 per cent of the ingots shall be taken as a sample, but in no case shall the number of ingots taken as a sample be less than ten.

The ingots taken as samples shall be drilled by templet. In the case of a shipment represented by a sufficient number of ingots, one line of holes on the templet shall be used for each ingot, *i.e.*, ingot No. 1 shall be drilled at the base, ingot No. 2 shall be drilled with one line of holes further up, etc., the resultant sample being a representation of the total sample of one whole ingot. In cases where the ingots in the sample are less than the number of lines of holes in the templet, the sample shall be drilled using sufficient lines and fractions thereof to insure at all times a sample representative of one whole ingot. In all cases, the drilling shall be done through the ingots. The drillings obtained in the above manner shall be thoroughly mixed and divided by split sampler until the sample is about 100 g.

Methods of Analysis.

5. The chemical analysis shall be made in accordance with the Standard Methods of Chemical Analysis of Nickel (Serial Designation: B 41) of the American Society for Testing Materials.[1]

PACKAGES

Packages.

6. All packages and barrels shall be marked with a brand by which the maker and grade can be identified.

CLAIMS

Claims.

7. Claims in writing only shall be considered and must be submitted within 30 days of receipt of material at purchaser's plant, and with each claim shall be submitted the results of purchaser's tests. The seller shall be given one week from date of receipt of such claim to investigate his records and shall then agree either to satisfy the claim or to send a representative to the purchaser's mill.

(*a*) *Chemical Defects.*—No claims shall be considered unless the purchaser can submit to seller's representative the minimum sample of the grade specified in question.

(*b*) *Physical Defects.*—No claims shall be considered unless the purchaser can submit unused samples of the material in question to seller's representative.

Plant Treatment.

8. Where the material satisfied the chemical and physical requirements of these specifications, it shall not be condemned for defects of alloys in which it is used.

[1] See p. 686.

Investigation of Claims.

9. The maker's representative shall inspect all pieces where the physical defects are claimed. If agreement is not reached the question of fact shall be submitted to a mutually agreeable umpire, whose decision shall be final.

On a question of metal contents a sample shall be taken by representatives of both parties as described under that paragraph of Section 4 applicable to the material in question. The properly mixed sample shall be separated into three parts, each of which shall be placed in a sealed package, one for each party and one for an umpire, if necessary. Each party shall make analysis, as specified in Section 5, and if the results do not establish or dismiss the claim to the satisfaction of both parties, the third sample shall be submitted to a mutually agreeable umpire, who shall determine the question of quality, and whose determination shall be final.

Settlement of Claims.

10. The expenses of the seller's representative and of the umpire shall be paid by the loser or divided in proportion to concession made in case of compromise.

In case of rejection being established, damages shall be limited to payment of freight both ways by the seller and substitution of an equivalent weight of nickel meeting specifications for the grade in question.

STANDARD SPECIFICATIONS

FOR

ALUMINUM FOR USE IN THE MANUFACTURE OF IRON AND STEEL[1]

Serial Designation: B 37 – 26

These specifications are issued under the fixed designation B 37; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1920; ADOPTED, 1926.

Scope.

1. These specifications cover two grades of Virgin and four grades of Secondary Aluminum, as follows:

(*a*) *Virgin Aluminum.*

(1) *98.0 Grade*, containing not less than 98 per cent aluminum. This grade is identical with the 98.0 Grade specified in the Tentative Specifications for Aluminum Ingots for Remelting (Serial Designation: B 24 – 26 T) of the American Society for Testing Materials.[2]

(2) *94.0 Grade*, containing not less than 94 per cent aluminum. The remainder may be chiefly iron and silicon.

(*b*) *Secondary Aluminum.*

(1) *98.0 Grade*, containing not less than 98 per cent aluminum. This grade is generally made from sheet clippings. The remainder may be chiefly copper, iron and silicon.

(2) *94.0 Grade*, containing not less than 94 per cent aluminum. A maximum of 0.5 per cent of zinc will be allowed in this grade. The remainder may be chiefly copper.

(3) *90.0-A Grade*, containing not less than 90 per cent aluminum. A maximum of 0.5 per cent of zinc will be allowed in this grade. The remainder may be chiefly copper.

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee B-2 on Non-Ferrous Metals and Alloys.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 26, Part I, p. 713 (1927); also 1927 Book of A.S.T.M. Tentative Standards, p. 132.

(4) *90.0-B Grade*, containing not less than 90 per cent aluminum. A maximum of 4 per cent of zinc will be allowed in this grade. The remainder may be chiefly copper.

MANUFACTURE

2. The manufacturer shall use care to have each lot of metal as uniform as possible. **Quality.**

3. The aluminum may be in the form of ingots, rods or shot. **Ingots, Rods, Shot.**

Ingots should be of convenient size for use. Ingots with a minimum of five notches, weighing approximately 3 lb. will meet the requirements of these specifications.

Rods may be either rolled or cast and $\frac{3}{8}$ to $\frac{1}{2}$ in. in diameter.

Shot should be of convenient size. That produced by running the molten metal through $\frac{1}{8}$-in. diameter holes is satisfactory.

SAMPLING

4. If the aluminum is shipped in carload lots, random samples shall be taken but not less than five ingots for each car. If the shipment is in less than carload lots, one ingot shall be taken for each 10,000 lb. (4536 kg.) or fractional part thereof. **Sampling.**

5. The ingots selected shall be drilled completely through, or half through from top and bottom. The drillings shall be fine, thin chips. They shall be thoroughly mixed, and the sample for analysis shall not be less than 60 g. **Drilling.**

Rods shall be sampled in a similar manner, except that the drilling shall be radial.

An equivalent amount of shot shall be taken as a sample and reduced by quartering to a sample of convenient size.

ANALYSES

6. The chemical analysis shall be made in accordance with the Tentative Methods of Chemical Analysis of Aluminum and Light Aluminum Alloys (Serial Designation: B 40 – 27 T) of the American Society for Testing Materials.[1] **Analyses.**

MARKING

7. The maker's brand and the grade of aluminum shall be cast or rolled on each ingot or rod and marked plainly on each container of shot metal. When marking the grade by casting or rolling is not practicable, the grade shall be indicated by **Marking.**

[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I (1927); also 1927 Book of A.S.T.M. Tentative Standards, p. 152.

spotting each large ingot or one ingot or rod from each bundle with a designating color of paint, red indicating the 98.0 Virgin grade, yellow the 94.0 Virgin grade, red and white the Secondary 98.0 Grade, red and yellow the Secondary 94.0 Grade, red and blue the Secondary 90.0-A Grade, and red and black the Secondary 90.0-B Grade.

CLAIMS

Claims.

8. Claims, to be considered, shall be made in writing within ten days of receipt of material at the purchaser's plant, and the results of the purchaser's tests shall be given. The vender shall within ten days of such claim, either agree to satisfy the claim or send a representative to the purchaser's plant to resample the shipment as specified in Section 3. Samples so taken shall be sealed and submitted to a mutually agreeable umpire, whose determination shall be final.

Umpire Analysis Expense.

10. The expense of the umpire analysis shall be paid by the loser, or divided in proportion to the concession made, in case of compromise. In case rejection is established, the damage shall be limited to the payment of freight both ways by the vender for the substitution of an equivalent weight of metal meeting specifications.

STANDARD SPECIFICATIONS
FOR
PHOSPHOR TIN[1]

Serial Designation: B 51 – 27

These specifications are issued under the fixed designation B 51; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1924; ADOPTED, 1927.

Scope.

1. These specifications cover phosphor tin in one grade.

MANUFACTURE

Material.

2. The manufacturer shall use new tin of uniform quality throughout in the manufacture of phosphor tin.

3. The manufacturer or vendor shall furnish phosphor tin ingots in the form of notched slabs of a size that can be handled conveniently.

4. Phosphor tin shall be clean, free from defects, and uniform in quality.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition

5. The material shall conform to the following requirements as to chemical composition:

Phosphorus, minimum	3.50 per cent
Phosphorus plus tin, minimum	99.50 "

Sampling.

6. One ingot from each melt or portion of melt shall be selected and not less than 140 g. of clean fine drillings or sawdust shall be taken from the ingot and mixed thoroughly. The ingots selected shall be drilled completely through or one-half through from top to bottom, the surface material being rejected.

MARKING

Marking.

7. A brand and melt number shall be cast or otherwise plainly marked upon each slab or ingot by which the manufacturer and heat

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee B-2 on Non-Ferrous Metals and Alloys.

may be identified. Marking may be done either by stamping or painting.

CLAIMS

Claims. 8. Claims to be considered shall be made in writing within ten days of receipt of material at the purchaser's plant and the results of the purchaser's tests shall be given. The vendor shall within ten days of such claim, either agree to satisfy the claim or send a representative to the purchaser's plant to resample the shipment as specified in Section 6. Samples so taken shall be sealed and submitted to a mutually agreeable umpire, whose determination shall be final.

Umpire Analysis Expense. 9. The expenses of the umpire analysis shall be paid by the loser, or divided in proportion to the concession made, in case of compromise. In case rejection is established, the damage shall be limited to the payment of freight both ways by the vendor for the substitution of an equivalent weight of metal meeting specifications.

STANDARD SPECIFICATIONS
FOR
PHOSPHOR COPPER[1]

Serial Designation: B 52 - 27

These specifications are issued under the fixed designation B 52; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1924; ADOPTED, 1927.

Scope.

1. These specifications cover phosphor copper in two grades, as follows:

Grade A, and
Grade B.

MANUFACTURE

Material.

2. The manufacturer shall use new metal, or new metal and scrap resulting from the manufacture of ingots of similar composition, in the manufacture of this material.

3. The manufacturer or vendor shall furnish phosphor copper as ingots in the form of notched slabs, weighing from 15 to 20 lb., unless otherwise specified in the contract.

4. Phosphor copper shall be clean, free from defects and uniform in quality.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

5. The material shall conform to the following requirements as to chemical composition:

	Phosphorus, Minimum, per cent	Phosphorus Plus Copper, Minimum, per cent	Iron, Maximum, per cent
Grade A	14.0	99.75	0.15
Grade B	10.0	99.75	0.15

Sampling.

6. One ingot from each melt or portion of melt shall be selected and not less than 140 g. of clean fine drillings or sawdust shall be taken from the ingot and mixed thoroughly. The ingots selected shall be drilled completely through or one-half through from top and bottom, the surface material being rejected.

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee B-2 on Non-Ferrous Metals and Alloys.

MARKING

Marking. 7. A brand and melt number shall be cast or otherwise plainly marked upon each slab or ingot by which the manufacturer and heat may be identified. Marking may be done either by stamping or painting.

CLAIMS

Claims. 8. Claims to be considered shall be made in writing within ten days of receipt of material at the purchaser's plant, and the results of the purchaser's tests shall be given. The vendor shall within ten days of such claim, either agree to satisfy the claim or send a representative to the purchaser's plant to resample the shipment as specified in Section 6. Samples so taken shall be sealed and submitted to a mutually agreeable umpire, whose determination shall be final.

Umpire Analysis Expense. 9. The expenses of the umpire analysis shall be paid by the loser, or divided in proportion to the concession made, in case of compromise. In case rejection is established, the damage shall be limited to the payment of freight both ways by the vendor for the substitution of an equivalent weight of metal meeting specifications.

STANDARD SPECIFICATIONS
FOR
SILICON COPPER[1]

Serial Designation: B 53 - 27

These specifications are issued under the fixed designation B 53; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1924; ADOPTED, 1927.

1. These specifications cover silicon copper in one grade. **Scope.**

MANUFACTURE

2. The manufacturer shall use new metal, or new metal and scrap resulting from the manufacture of ingots of similar composition in the manufacture of this material. **Material.**

3. The manufacturer or vendor shall furnish silicon copper in the form of ingots or notched slabs of such size that they can be handled conveniently.

4. Silicon copper shall be clean, free from defects, and uniform in quality.

CHEMICAL PROPERTIES AND TESTS

5. The material shall conform to the following requirements as to chemical composition: **Chemical Composition.**

Silicon	10 to 12 per cent
Tin, maximum	0.25 "
Zinc, maximum	0.25 "
Iron, maximum	0.75 "
Aluminum, maximum	0.25 "
Copper	Remainder

The sum of the copper, silicon and iron content shall be not less than 99.4 per cent.

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee B-2 on Non-Ferrous Metals and Alloys.

Sampling.

6. One ingot from each melt or portion of melt shall be selected and not less than 140 g. of clean fine drillings or sawdust shall be taken from the ingot and mixed thoroughly. The ingots selected shall be drilled completely through or one-half through from top and bottom, the surface material being rejected.

MARKING

Marking.

7. A brand and melt number shall be cast or otherwise plainly marked upon each slab or ingot by which the manufacturer and heat may be identified. Marking may be done either by stamping or painting.

CLAIMS

Claims.

8 Claims to be considered shall be made in writing within ten days of receipt of material at the purchaser's plant, and the results of the purchaser's tests shall be given. The vendor shall within ten days of such claim, either agree to satisfy the claim or send a representative to the purchaser's plant to resample the shipment as specified in Section 6. Samples so taken shall be sealed and submitted to a mutually agreeable umpire, whose determination shall be final.

Umpire Analysis Expense.

9. The expenses of the umpire analysis shall be paid by the loser, or divided in proportion to the concession made, in case of compromise. In case rejection is established, the damage shall be limited to the payment of freight both ways by the vendor for the substitution of an equivalent weight of metal meeting specifications.

STANDARD SPECIFICATIONS

FOR

HOT-ROLLED COPPER RODS FOR WIRE DRAWING[1]

Serial Designation: B 49 – 26

These specifications are issued under the fixed designation B 49; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1923; ADOPTED IN AMENDED FORM, 1926.

Scope.

1. These specifications cover black hot-rolled copper rods for wire-drawing purposes.

MANUFACTURE

Material.

2. The copper shall conform in quality and purity to the requirements of either the Standard Specifications for Lake Copper Wire Bars, Cakes, Slabs, Billets, Ingots, and Ingot Bars (Serial Designation: B 4)[2] or of the Standard Specifications for Electrolytic Copper Wire Bars, Cakes, Slabs, Billets, Ingots, and Ingot Bars (Serial Designation: B 5)[3] of the American Society for Testing Materials.

Rolling.

3. (*a*) The rod shall be hot rolled from standard wire bars.

(*b*) The rods shall be furnished in one continuous length without joints.

PHYSICAL PROPERTIES AND TESTS

Physical Tests.

4. (*a*) The rods shall conform to the following requirements as to tensile properties:

The elongation in 10 in. shall not be less than 25 per cent. The elongation shall be measured between bench marks placed upon the wire originally 10 in. apart and the fracture shall be between the bench marks and not closer than 1 in. to either bench mark. If upon testing a sample from any coil or reel the results do not conform to the specified requirements, two additional samples shall be tested and the average of the three tests shall determine acceptance or rejection of the coil or reel.

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee B-1 on Copper Wire.

[2] See p. 515. [3] See p. 520.

(*b*) Two tests shall be made from each carload of 50,000 lb. or less.

Electric Resistivity. 5. Electric resistivity shall be determined upon fair samples by resistance measurements at a temperature of 20° C. (68° F.) and shall not exceed 891.58 lb. per mile-ohm.

DIMENSIONS AND PERMISSIBLE VARIATIONS

Dimensions and Permissible Variations. 6. (*a*) The size shall be expressed as the diameter of the rod in decimal fractions of an inch.

(*b*) The rods shall be hot rolled to nominal size within the following permissible variations:

Diameter, in.	Permissible Variations, in.	Diameter, in.	Permissible Variations, in.
0.250	+0.020	0.875	±0.020
0.3125	±0.010	1.00	±0.020
0.375	±0.010	1.125	±0.020
0.500	±0.015	1.250	±0.020
0.625	±0.015	1.375	±0.030
0.750	±0.015		

Sizes between those listed shall take the variation for the next larger size in the table.

Density. 7. For the purpose of calculating weights, cross-sections, etc., the density of copper shall be taken as 8.89 g. per cu. cm. at 20° C. (68° F.).

FINISH

Finish. 8. The rod shall be free from all imperfections not consistent with the best commercial practice.

PACKING

Packages. 9. Unless otherwise agreed upon, the rods shall be shipped in coils approximately 24 in. in inside diameter and each coil shall be bound tightly together with copper wire at two points approximately opposite to each other.

INSPECTION

Inspection. 10. The tests and inspection shall be made at the place of manufacture. The manufacturer shall afford the inspector representing the purchaser all reasonable facilities to assure him that the material conforms to all the requirements of the specifications.

STANDARD SPECIFICATIONS
FOR
HARD-DRAWN COPPER WIRE[1]

Serial Designation: B 1 – 27

These specifications are issued under the fixed designation B 1; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ADOPTED, 1909; REVISED, 1911, 1913, 1915, 1923, 1927.

1. These specifications cover hard-drawn round wire. **Scope.**

MANUFACTURE

2. The material shall be copper of such quality and purity that, when drawn hard, it shall have the properties and characteristics herein specified. **Material.**

PHYSICAL PROPERTIES AND TESTS

3. (*a*) The wire shall be so drawn that its tensile strength and elongation shall be at least equal to the value stated in Table I. Tension tests shall be made upon fair samples, and the elongation of wire larger in diameter than 0.204 in. shall be determined as the permanent increase in length, due to the breaking of the wire in tension, measured between bench marks placed upon the wire originally 10 in. apart. The elongation of wire 0.204 in. in diameter or smaller shall be determined by measurements made between the jaws of the testing machine. The zero length shall be the distance between the jaws when a load equal to 10 per cent of the specified tensile strength shall have been applied, and the final length shall be the distance between the jaws at the time of rupture. The zero length shall be as near 60 in. as possible. The fracture shall be between the bench marks in the case of wire larger than 0.204 in. in diameter and between the jaws in the case of smaller wire, and not closer than 1 in. to either bench mark or jaw. **Tensile Strength and Elongation.**

(*b*) If upon testing a sample from any coil of wire, the results are found to be below the values stated in the table, tests upon two additional samples shall be made, and the average of the three tests

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee B-1 on Copper Wire.

shall determine the acceptance or rejection of the coil. For wire whose nominal diameter is between listed sizes, the requirements shall be those of the next larger size included in Table I (Note 1).

(*c*) Tests upon a section of wire containing a braze shall show at least 95 per cent of the tensile strength of the unbrazed wire. Elongation tests are not to be made upon test sections including brazes.

Electric Resistivity.

4. Electric resistivity (Note 2) shall be determined upon fair samples by resistance measurements at a temperature of 20° C. (68° F.).

The wire shall not exceed the following limits:

For diameters 0.460 to 0.325 in., 900.77 lb. per mile-ohm at 20° C.;

For diameters 0.324 to 0.040 in., 910.15 lb. per mile-ohm at 20° C.

TABLE I.—REQUIREMENTS FOR TENSILE STRENGTH AND ELONGATION.

Diameter, in.	Area, circular mils.	Tensile Strength, lb. per sq. in.	Elongation, per cent		Diameter, in.	Area, circular mils.	Tensile Strength, lb. per sq. in.	Elongation in 60 in., per cent
			in 10 in.	in 60 in.				
0.460.....	211 600	49 000	3.75	.....	0.114.....	12 995	64 300	1.02
0.410.....	168 100	51 000	3.25	.....	0.104.....	10 815	64 800	1.00
0.365.....	133 225	52 800	2.80	.....	0.102.....	10 404	64 900	1.00
0.325.....	105 625	54 500	2.40	.....	0.092.....	8 464	65,400	0.97
0.289.....	83 520	56 100	2.17	.....	0.091.....	8 281	65 400	0.97
0.258.....	66 565	57 600	1.98	.....	0.081.....	6 561	65 700	0.95
0.229.....	52 440	59 000	1.79	.....	0.080.....	6 400	65 700	0.94
0.204.....	41 615	60 100	.....	1.24	0.072.....	5 184	65 900	0.92
0.182.....	33 125	61 200	.....	1.18	0.065.....	4 225	66 200	0.91
0.165.....	27 225	62 000	.....	1.14	0.064	4 096	66 200	0.90
0.162.....	26 245	62 100	.....	1.14	0.057.....	3 249	66 400	0.89
0 144.....	20 735	63 000	.....	1.09	0.051.....	2 601	66 600	0.87
0.134.....	17 956	63 400	.....	1.07	0.045.....	2 025	66 800	0.86
0.128.....	16 385	63 700	.....	1.06	0.040.....	1 600	67 000	0.85

DIMENSIONS AND PERMISSIBLE VARIATIONS

Dimensions and Permissible Variations.

5. (*a*) The size shall be expressed as the diameter of the wire in decimal fractions of an inch, using not more than three places of decimals; that is, in mils (Note 3).

(*b*) Wire is expected to be accurate in diameter; permissible variations from nominal diameter shall be:

For wire 0.100 in. in diameter and larger, one per cent over or under;

For wire less than 0.100 in. in diameter, one mil over or under.

(*c*) Each coil is to be gaged at three places, one near each end, and one approximately at the middle; the coil may be rejected if, two points being within the accepted limits, the third point is off gage more than 2 per cent in the case of wire 0.064 in. in diameter

or larger, or more than 3 per cent in the case of wire less than 0.064 in. in diameter.

6. For the purpose of calculating weights, cross-sections, etc., the density of copper shall be taken as 8.89 g. per cu. cm. at 20° C. (68° F.) (Note 4). **Density.**

FINISH

7. (*a*) The wire shall be free from all imperfections not consistent with the best commercial practice. **Finish.**

(*b*) Necessary brazes in hard-drawn wire shall be made in accordance with the best commercial practice.

PACKING

8. (*a*) Package sizes for round wire shall be agreed upon in the placing of individual orders. **Packages.**

(*b*) The wire shall be protected against damage in ordinary handling and shipping.

INSPECTION

9. All testing and inspection shall be made at the place of manufacture. The manufacturer shall afford the inspector representing the purchaser all reasonable facilities to enable him to satisfy himself that the material conforms to the requirements of these specifications. **Inspection.**

EXPLANATORY NOTES

NOTE 1.—Many other physical tests than those provided in these specifications are included in existing specifications. The reasons for the omission of some of the more common are given as follows:

Twist Tests.—The wire is sometimes required to permit twisting through a stated number of revolutions before breaking. The results are so easily influenced by temperature, speed of rotation, method of gripping, and other variables not easily defined or controlled, that the test is at least of doubtful value. It is the opinion of the committee that it is impractical to so define the conditions of the test that a twist test can be made definite and reliable; hence there is no warrant for its inclusion in specifications.

Wrap Tests.—Wire is sometimes required to permit tight wrapping about a wire of its own diameter, unwrapping and again re-wrapping. It is obvious that the making of a test of this kind with wire that is already hard-drawn is exceedingly difficult. Every one who has tried to break off a piece of tough wire by bending it back and forth between the fingers, knows how hard it is to confine the bend to one place, because of the hardening action of the previous bends. Hard wire which has been wrapped around a wire of small diameter is hardened still more and it is almost impossible to straighten the wire, let alone re-coil it in the opposite direction. In the opinion of the committee, it is inad-

visable to include a test which at best is so indefinite as a wrap test. Furthermore, it is the opinion of the committee that wire which will meet the physical tests included in these specifications will meet any properly made twist or wrap test that would reasonably be required.

Since the adoption of the Standard Specifications for Hard-Drawn Copper Wire, proposed in 1909, the committee has very carefully considered the matter of twist and wrap tests, and it is their final opinion that while there might be some possible reason for requiring that wire shall stand wrapping around a wire of equal diameter, there can be no good reason for including in specifications the requirement that it shall stand unwrapping and re-wrapping, because such a test is indefinite and cannot be made otherwise. It is almost physically impossible to unwrap and re-wrap hard-drawn wire about a wire of its own diameter. With respect to twist tests, the committee has nothing to add to the statement already on record, condemning this character of test.

Elastic Limit.—During the tension test on wire, there is seldom to be observed any definite drop of the beam or increase in the rate of elongation, corresponding to the yield point commonly observed in testing steel. The only way in which the elastic limit of hard wire may be determined is by the actual plotting of the elastic curve from extensometer readings. Even such tests are difficult of interpretation, because the wire when available for tests is usually curved, due to its having been put up in a coil. There are little sets observable before the true elastic limit has been reached, owing to the fact that one side of the wire, having been stretched in coiling, is really a little harder than the other side, and the pull is, therefore, not even. Considering the difficulty of making the test and the uncertainty of the results obtained, it is the opinion of the committee that it would be inadvisable to include an elastic limit test in these specifications. It is evident that if the designing engineer requires a knowledge of the location of the elastic limit, for purposes of calculation in designing, such data can be obtained by special tests on representative sizes of wire, which will fix the relation of the elastic limit to the ultimate strength for all wire which is properly made.

Tests carefully made by members of the committee show that the elastic limit of hard-drawn copper wire from sizes 0.460 to 0.325 in., inclusive, averages 55 per cent of the tensile strength required in these specifications, with a minimum value of 50 per cent; for sizes 0.324 to 0.040 in., inclusive, it averages 60 per cent of the tensile strength required in these specifications, with a minimum value of 55 per cent. This statement of experience is based on the definition of elastic limit as "that point on the elastic curve beyond which the ratio of stress to strain ceases to be constant."

NOTE 2.—*Conductivity.*—Electric conductivity was formerly expressed as a percentage on the basis of a determination made by Matthiessen about 1865, of the electric resistivity of supposedly pure copper. Since that time the methods of refining copper have advanced, so that it is not uncommon to find copper of over 100 per cent conductivity on the Matthiessen basis. There has until recently not been international agreement on the electric resistivity of copper to be considered the standard for the expression of conductivity. While international agreement upon the value 0.15328 ohms per meter-gram at 20° C. for the resistivity of copper equal to 100-per-cent conductivity was reached by the International Electrotechnical Commission in 1913, it has been deemed preferable to express the requirements in standard specifications

in the terms of quantities directly measurable, rather than by reference to some quantity whose standard value is the subject of agreement only. The use of the arbitrary term "conductivity" has no more warrant than the employment of arbitrary gage numbers. Therefore, in these specifications the requirements are stated as the maximum rejection limits to the resistivity.

For the convenience of those who are accustomed to express resistivity in any of the several more or less common units, the following table of equivalents has been prepared, giving the resistivity of copper at 20° C.:

900.77 lb. per mile-ohm is equal to:

0.15775 ohms per meter-gram,
1.7745 microhms per centimeter-cube,
0.69863 microhms per inch-cube,
10.674 ohms per mil-foot.

910.15 lb. per mile-ohm is equal to:

0.15940 ohms per meter-gram,
1.7930 microhms per centimeter-cube,
0.70590 microhms per inch-cube,
10.785 ohms per mil-foot.

NOTE 3.—The use of arbitrary gage numbers to express dimensions cannot be too strongly condemned. There are many such gages in existence, and confusion is to be expected unless the particular gage to be used is specified. Many of the gages have their dimensions stated in absurd figures, such as 0.090742 in., when it is not especially easy to measure dimensions in the fourth decimal place by workshop tools. Definite diameters in measurable units are evidently preferable.

NOTE 4.—Unit weights were formerly defined in these specifications on the basis of specific gravity of copper. This has been changed to basis of density to agree literally with the definition of the Annealed Copper Standard adopted by the International Electrotechnical Commission.

STANDARD SPECIFICATIONS
FOR
MEDIUM HARD-DRAWN COPPER WIRE[1]

Serial Designation: B 2 – 27

These specifications are issued under the fixed designation B-2; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ADOPTED, 1912; REVISED, 1913, 1915, 1927.

Scope.

1. These specifications cover medium hard-drawn round wire (Note 1).

MANUFACTURE

Material.

2. The material shall be copper of such quality and purity that, when drawn medium-hard, it shall have the properties and characteristics herein specified.

PHYSICAL PROPERTIES AND TESTS

Tensile Strength and Elongation.

3. (*a*) The wire shall be so drawn that its tensile strength shall not be greater than the maximum values and not less than the minimum values given in Table I, and its elongation shall not be less than the minimum values given in Table I. Tension tests shall be made upon fair samples, and the elongation of wire larger in diameter than 0.204 in. shall be determined as the permanent increase in length, due to the breaking of the wire in tension, measured between bench marks placed upon the wire originally 10 in. apart. The elongation of wire 0.204 in. in diameter and smaller shall be determined by measurements made between the jaws of the testing machine. The zero length shall be the distance between the jaws when a load equal to 10 per cent of the specified tensile strength shall have been applied, and the final length shall be the distance between the jaws at the time of rupture. The zero length shall be as near 60 in. as possible. The fracture shall be between the bench marks in the case of wire larger than 0.204 in. in diameter and between the jaws in the case of smaller wire, and not closer than 1 in. to either bench mark or jaw.

(*b*) If upon testing a sample from any coil of wire, the results are found to be below the values given in the table, tests upon two

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee B-1 on Copper Wire.

additional samples shall be made, and the average of the three tests shall determine acceptance or rejection of the coil. For wire whose nominal diameter is between listed sizes, the requirements shall be those of the next larger size included in Table I (Note 2).

(*c*) Tests upon a section of wire containing a braze shall show at least 95 per cent of the tensile strength of the unbrazed wire. Elongation tests are not to be made upon test sections including brazes.

TABLE I.

Diameter, in.	Tensile Strength, lb. per sq. in.		Elongation, per cent	
	Minimum	Maximum	in 10 in.	in 60 in.
0.460	42 000	49 000	3.75	.....
0.410	43 000	50 000	3.6	.....
0.365	44 000	51 000	3.25	.....
0.325	45 000	52 000	3.0	.....
0.289	46 000	53 000	2.75	.....
0.258	47 000	54 000	2.5	.....
0.229	48 000	55 000	2.25	.....
0.204	48 330	55 330	.....	1.25
0.182	48 600	55 660	.....	1.20
0.162	49 000	56 000	.....	1.15
0.144	49 330	56 330	.....	1.11
0.128	49 660	56 660	.....	1.08
0.114	50 000	57 000	.....	1.06
0.102	50 330	57 330	.....	1.04
0.091	50 660	57 660	.....	1.02
0.081	51 000	58 000	.....	1.00
0.072	51 330	58 330	.....	0.98
0.064	51 660	58 660	.....	0.96
0.057	52 000	59 000	.....	0.94
0.051	52 330	59 330	.....	0.92
0.045	52 660	59 660	.....	0.90
0.040	53 000	60 000	.....	0.88

Electric Resistivity.

4. Electric resistivity (Note 3) shall be determined upon fair samples by resistance measurements at a temperature of 20° C. (68° F.).

The wire shall not exceed the following limits:

For diameters 0.460 in. to 0.325 in., 896.15 lb. per mile-ohm at 20° C.

For diameters 0.324 in. to 0.040 in., 905.44 lb. per mile-ohm at 20° C.

DIMENSIONS AND PERMISSIBLE VARIATIONS

Dimensions and Permissible Variations.

5. (*a*) The size shall be expressed as the diameter of the wire in decimal fractions of an inch, using not more than three places of decimals; that is, in mils (Note 4).

(*b*) Wire is expected to be accurate in diameter; permissible variations from nominal diameter shall be:

For wire 0.100 in. in diameter or larger, one per cent over or under;

For wire less than 0.100 in. in diameter, one mil over or under.

(*c*) Each coil shall be gaged at three places, one near each end, and one approximately at the middle; the coil may be rejected, if, two points being within the accepted limits, the third point is off gage more than 2 per cent in the case of wire 0.064 in. in diameter or larger, or more than 3 per cent in the case of wire less than 0.064 in. in diameter.

Density. 6. For the purpose of calculating weights, cross-sections, etc., the density of copper shall be taken as 8.89 g. per cu. cm. at 20° C. (68° F.) (Note 5).

FINISH

Finish. 7. (*a*) The wire shall be free from all imperfections not consistent with the best commercial practice.

(*b*) Necessary brazes in medium hard-drawn wire shall be made in accordance with the best commercial practice.

PACKING

Packages. 8. (*a*) Package sizes for round wire shall be agreed upon in the placing of individual orders.

(*b*) The wire shall be protected against damage in ordinary handling and shipping.

INSPECTION

Inspection. 9. All testing and inspection shall be made at the place of manufacture. The manufacturer shall afford the inspector representing the purchaser all reasonable facilities to enable him to satisfy himself that the material conforms to the requirements of these specifications.

EXPLANATORY NOTES

NOTE 1.—*Definition.—Medium Hard-Drawn Wire* is essentially and necessarily a special product, because when wire has once started on its course through the drawing operations, it can only finish as a hard-drawn wire to be used as such or to be annealed and become soft or annealed wire. Medium hard-drawn wire is annealed wire drawn to a slightly smaller diameter.

NOTE 2.—Medium hard-drawn wire approaches hard-drawn wire in its characteristics, but from the very nature of the product, exact uniformity in tensile strength cannot be obtained; hence, the necessity for establishing a range of tensile strength within which standard medium hard-drawn wire must be expected to be found. In the opinion of the committee, any narrowing or reduction in the range permitted in tensile strength can only result in an unjustifiable increase in the cost of production of the wire.

Many other physical tests than those provided in these specifications are included in existing specifications. The reasons for the omission of some of the more common are given as follows:

Twist Tests.—The wire is sometimes required to permit twisting through a stated number of revolutions before breaking. The results are so easily influenced by temperature, speed of rotation, method of gripping, and other variables not easily defined or controlled, that the test is at least of doubtful value. It is the opinion of the committee that it is impractical to so define the conditions of the test that a twist test can be made definite and reliable; hence there is no warrant for its inclusion in specifications.

Wrap Tests.—Wire is sometimes required to permit tight wrapping about a wire of its own diameter, unwrapping and again re-wrapping. It is obvious that the making of a test of this kind with wire that is already hard is exceedingly difficult. Every one who has tried to break off a piece of tough wire by bending it back and forth between the fingers, knows how hard it is to confine the bend to one place, because of the hardening action of the previous bends. Hard wire which has been wrapped around a wire of small diameter is hardened still more and it is almost impossible to straighten the wire, let alone re-coil it in the opposite direction. In the opinion of the committee, it is inadvisable to include a test which at best is so indefinite as a wrap test. Furthermore, it is the opinion of the committee that wire which will meet the physical tests included in these specifications will meet any properly made twist or wrap test that would reasonably be required.

The committee has carefully considered the matter of twist and wrap tests in connection with both hard-drawn and medium hard-drawn wire, and it is their final opinion that while there might be some possible reason for requiring that wire shall stand wrapping around a wire of equal diameter, there can be no good reason for including in specifications the requirement that it shall stand unwrapping and re-wrapping, because such a test is indefinite and cannot be made otherwise. It is almost physically impossible to unwrap and re-wrap hard-drawn wire about a wire of its own diameter.

Elastic Limit.—During the tension test on wire, there is seldom to be observed any definite drop of the beam or increase in the rate of elongation, corresponding to the yield point commonly observed in testing steel. The only way in which the elastic limit of hard wire may be determined is by the actual plotting of the elastic curve from extensometer readings. Even such tests are difficult of interpretation, because the wire when available for tests is usually curved, due to its having been put up in a coil. There are little sets observable before the true elastic limit has been reached, owing to the fact that one side of the wire, having been stretched in coiling, is really a little harder than the other side, and the pull is, therefore, not even. Considering the difficulty of making the test and the uncertainty of the results obtained, it is the opinion of the committee that it would be inadvisable to include an elastic limit test in these specifications. It is evident that if the designing engineer requires a knowledge of the location of the elastic limit, for purposes of calculation in designing, such data can be obtained by special tests on representative sizes of wire, which will fix the relation of the elastic limit to the ultimate strength for all wire which is properly made.

Tests carefully made by members of the committee show that the elastic limit of medium hard-drawn wire averages 50 per cent of the ultimate tensile

strength required in these specifications. This statement of experience is based on the definition of elastic limit as "that point on the elastic curve beyond which the ratio of stress to strain ceases to be constant."

NOTE 3.—*Conductivity.*—Electric conductivity was formerly expressed as a percentage on the basis of a determination made by Matthiessen about 1865, of the electric resistivity of supposedly pure copper. Since that time the methods of refining copper have advanced, so that it is not uncommon to find copper of over 100 per cent conductivity on the Matthiessen basis. There has until recently not been international agreement on the electric resistivity of copper to be considered the standard for the expression of conductivity. While international agreement upon the value 0.15328 ohms per meter-gram at 20° C. for the resistivity of copper equal to 100 per cent conductivity was reached by the International Electrotechnical Commission in 1913, it has been deemed preferable to express the requirements in standard specifications in the terms of quantities directly measurable, rather than by reference to some quantity whose standard value is the subject of agreement only. The use of the arbitrary term "conductivity" has no more warrant than the employment of arbitrary gage numbers. Therefore, in these specifications the requirements are stated as the maximum rejection limits to the resistivity.

For the convenience of those who are accustomed to express resistivity in any one of the several more or less common units, the following table of equivalents has been prepared, giving the resistivity of copper at 20° C.:

896.15 lb. per mile-ohm is equal to:
- 0.15694 ohms per meter-gram,
- 1.7654 microhms per centimeter-cube,
- 0.69504 microhms per inch-cube,
- 10.619 ohms per mil-foot.

905.44 lb. per mile-ohm is equal to:
- 0.15857 ohms per meter-gram,
- 1.7837 microhms per centimeter-cube,
- 0.70224 microhms per inch-cube,
- 10.729 ohms per mil-foot.

NOTE 4.—The use of arbitrary gage numbers to express dimensions cannot be too strongly condemned. There are many such gages in existence, and confusion is to be expected unless the particular gage to be used is specified. Many of the gages have their dimensions stated in absurd figures, such as 0.090742 in., when it is not especially easy to measure dimensions in the fourth decimal place by work-shop tools. Definite diameters in measurable units are evidently preferable.

NOTE 5.—Unit weights were formerly defined in these specifications on the basis of specific gravity of copper. This has been changed to basis of density to agree literally with the definition of the Annealed Copper Standard adopted by the International Electrotechnical Commission.

STANDARD SPECIFICATIONS

FOR

SOFT OR ANNEALED COPPER WIRE[1]

Serial Designation: B 3 – 27

These specifications are issued under the fixed designation B 3; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ADOPTED, 1912; REVISED, 1913, 1915, 1927.

Scope.

1. These specifications cover untinned drawn and annealed round wire (Note 1).

MANUFACTURE

Material.

2. The material shall be copper of such quality and purity that when drawn and annealed, it shall have the properties and characteristics herein specified.

PHYSICAL PROPERTIES AND TESTS

Tensile Strength and Elongation.

3. (*a*) The wire shall be so drawn and annealed that its tensile strength shall not be greater than the value stated in Table I, and its elongation not less than the value stated in Table I. Tension tests shall be made upon fair samples, and the elongation shall be determined as the permanent increase in length, due to the breaking of the wire in tension, measured between bench marks placed upon the wire originally 10 in. apart. The fracture shall be between the bench marks and not closer than 1 in. to either bench mark.

(*b*) If upon testing a sample from any coil, reel or spool of wire, the results are found to be below the value given in the table for elongation or above the value given for tensile strength, tests upon two additional samples shall be made, and the average of the three tests shall determine the acceptance or rejection of the coil. For wire whose nominal diameter is between listed sizes, the requirements shall be those of the next larger size included in Table I.

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee B-1 on Copper Wire.

Electric Resistivity.

4. Electric resistivity (Note 2) shall be determined upon fair samples by resistance measurements at a temperature of 20° C. (68° F.), and it shall not exceed 891.58 lb. per mile-ohm.

DIMENSIONS AND PERMISSIBLE VARIATIONS

Dimensions and Permissible Variations.

5. (*a*) The size shall be expressed as the diameter of the wire in decimal fractions of an inch (Note 3).

(*b*) Wire is expected to be accurate in diameter; permissible variations from nominal diameter shall be:

For wire 0.010 in. in diameter or larger, one per cent over or under;

For wire less than 0.010 in. in diameter, 0.1 mil (0.0001 in.) over or under.

(*c*) Each coil shall be gaged at three places, one near each end and one approximately at the middle; from spools, approximately 12 ft. shall be reeled off, the wire shall be gaged in six places between the second and twelfth foot from the end. The coils or spools will

TABLE I.

Diameter, in.	Tensile Strength, lb. per sq. in.	Elongation in 10 in., per cent
0.460 to 0.290	36 000	35
0.289 " 0.103	37 000	30
0.102 " 0.021	38 500	25
0.020 " 0.003	40 000	20

be rejected if the average of the measurements obtained is not within the limits specified in Paragraph (*b*).

Density.

6. For the purpose of calculating weights, cross-sections, etc., the density of copper shall be taken as 8.89 g. per cu. cm. at 20° C. (68° F.) (Note 4).

FINISH

Finish.

7. (*a*) The wire shall be free from all imperfections not consistent with the best commercial practice.

(*b*) Necessary brazes in soft or annealed wire shall be made in accordance with the best commercial practice.

PACKING

Packages.

8. (*a*) Wire may be shipped in coils or on reels as agreed upon by the purchaser and manufacturer (Note 5). Table II gives the maximum and minimum weights of wire of the stated sizes which may be shipped in any one package, whether coil, reel or spool; in the case of wire larger than 0.010 in. in diameter, the maximum and minimum

package weights are net, and in the case of wire 0.010 in. or less in diameter, the maximum package weights are gross, and the minimum package weights are net. The table also gives the limiting dimensions of the coils, reels and spools on which wire may be shipped. The length and diameter specified for reels and spools are to be measured over all and are maximum sizes; reels or spools smaller than these may be used provided the minimum weights called for are carried by the reel or spool. In Table II, there are also given the diameters of the draw-block on which the final drawing of the wire is to be made, when wire is shipped in coils; it being understood that the wire is not to be re-wound after final drawing. This provision is made to insure that

TABLE II.

Diameters, in.	Package Weights, lb.		Diam. of Draw-Block, in.	Dimensions of Reels and Spools, in.		
	Max.	Min.		Max. Diameter	Max. Length	Diameter of Hole for Rod
0.460 to 0.360	520	290	24	32	21	$1\frac{1}{2}$ to $2\frac{1}{2}$
0.359 " 0.258	430	290	24	32	21	$1\frac{1}{2}$ " $2\frac{1}{2}$
0.257 " 0.129	290	140	22	24	12	$1\frac{1}{2}$ " $2\frac{1}{2}$
0.128 " 0.102	230	95	22	24	12	$\frac{5}{8}$ " $1\frac{1}{2}$
0.101 " 0.083	230	75	22	24	12	$\frac{5}{8}$ " $1\frac{1}{2}$
0.082 " 0.081	200	75	16	24	12	$\frac{5}{8}$ " $1\frac{1}{2}$
0.080 " 0.064	200	50	16	24	12	$\frac{5}{8}$ " $1\frac{1}{2}$
0.063 " 0.051	120	50	16	24	10	$\frac{5}{8}$ " $1\frac{1}{2}$
0.050 " 0.041	100	50	16	24	10	$\frac{5}{8}$ " $1\frac{1}{2}$
0.040 " 0.032	50	20	8	24	8	$\frac{5}{8}$ " $1\frac{1}{8}$
0.031 " 0.020	25	15	8	10	$6\frac{1}{2}$	$\frac{5}{8}$ " $\frac{7}{8}$
0.019 " 0.011	10	5	8	$5\frac{1}{2}$	4	$\frac{3}{8}$ " $\frac{11}{16}$
0.010 " 0.008	5	$2\frac{1}{2}$	8	4	4	$\frac{3}{8}$ " $\frac{11}{16}$
0.007 " 0.0056	$2\frac{1}{2}$	1	6	$2\frac{1}{2}$	4	$\frac{3}{8}$ " $\frac{11}{16}$
0.005	$1\frac{1}{2}$	$\frac{5}{8}$	6	$2\frac{1}{2}$	4	$\frac{3}{8}$ " $\frac{11}{16}$
0.004	$1\frac{1}{2}$	$\frac{3}{8}$	6	$2\frac{1}{2}$	4	$\frac{3}{8}$ " $\frac{11}{16}$
0.003	1	$\frac{1}{4}$	6	$2\frac{1}{2}$	4	$\frac{3}{8}$ " $\frac{11}{16}$

coils of wire of a given gage, when supplied by different manufacturers, will be of the same general dimensions.

Wire 0.204 in. in diameter or larger may be shipped in larger packages when agreed upon.

(*b*) The wire shall be protected against damage in ordinary handling and shipping.

INSPECTION

9. All testing and inspection shall be made at the place of manufacture. The manufacturer shall afford the inspector representing the purchaser all reasonable facilities to enable him to satisfy himself that the material conforms to the requirements of these specifications. **Inspection.**

EXPLANATORY NOTES

NOTE 1.—Soft or annealed copper wire is wire which has been drawn by customary operations and annealed, and finished by cleaning when necessary to remove scale or oxide. The wire is so soft and ductile that it is easily marred and even stretched by careless handling in the operations of winding or cabling, hence, the necessity for confining specifications and inspection to wire in packages as it leaves the manufacturer, and before being put through processes incident to its use by the purchaser.

NOTE 2.—Electric conductivity was formerly expressed as a percentage on the basis of a determination made by Matthiessen about 1865, of the electric resistivity of supposedly pure copper. Since that time the methods of refining copper have advanced, so that it is not uncommon to find copper of over 100 per cent conductivity on the Matthiessen basis. There has until recently not been international agreement on the electric resistivity of copper to be considered the standard for the expression of conductivity. While international agreement upon the value 0.15328 ohms per meter-gram at 20° C. for the resistivity of copper equal to 100 per cent conductivity was reached by the International Electrotechnical Commission in 1913, it has been deemed preferable to express the requirements in standard specifications in the terms of quantities directly measurable, rather than by reference to some quantity whose standard value is the subject of agreement only. The use of the arbitrary term "conductivity" has no more warrant than the employment of arbitrary gage numbers. Therefore, in these specifications the requirements are stated as the maximum rejection limits to the resistivity.

For convenience of those who are accustomed to express resistivity in any one of the several more or less common units, the following table of equivalents has been prepared, giving the resistivity of copper at 20° C.:

891.58 lb. per mile-ohm is equal to:

0.15614 ohms per meter-gram,
1.7564 microhms per centimeter-cube,
0.69150 microhms per inch-cube,
10.565 ohms per mil-foot.

NOTE 3.—The use of arbitrary gage numbers to express dimensions cannot be too strongly condemned. There are many such gages in existence, and confusion is to be expected unless the particular gage to be used is specified. Many of the gages have their dimensions stated in absurd figures, such as 0.090742 in., when it is not especially easy to measure dimensions in the fourth decimal place by workshop tools. Definite diameters in measurable units are evidently preferable.

NOTE. 4.—Unit weights were formerly defined in these specifications on the basis of specific gravity of copper. This has been changed to basis of density to agree literally with the definition of the Annealed Copper Standard adopted by the International Electrotechnical Commission.

NOTE 5.—Attention is called to the necessity for the purchaser and manufacturer agreeing on the package weights which will be standard under any individual contract. The committee has indicated limitations to standard package weights which in their opinion will provide packages of sufficient size to be desirable, and without being so large that the wire is apt to be damaged in handling.

STANDARD SPECIFICATIONS
FOR
TINNED SOFT OR ANNEALED COPPER WIRE FOR RUBBER INSULATION[1]

Serial Designation: B 33 – 21

These specifications are issued under the fixed designation B 33; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1919; ADOPTED, 1921.

Scope.

1. These specifications cover tinned soft or annealed copper wire suitable for use in making rubber insulated wires and cables.

MANUFACTURE

Manufacture.

2. The tinned wire shall be made by coating soft or annealed copper wire with pure tin. The copper used shall be of such quality and purity that after tinning it shall have the properties and characteristics hereinafter required.

CHEMICAL PROPERTIES AND TESTS

Continuity of Coating.

3. The continuity of the tin coating shall be determined by the Sodium-Polysulfide test, which shall be applied as specified in Sections 4 to 10.

(*A*) *Treatment of Samples.*

Length of Samples.

4. Samples shall have a length of about 6 in., and they shall be tagged or marked to correspond with the coil or reel from which they were cut.

Treatment of Samples.

5. The samples shall be thoroughly cleaned by immersion in benzine, redistilled petroleum ether, ether or carbon tetrachloride for at least 3 minutes, then removed and wiped dry with a clean, soft cloth. The samples thus cleaned shall be kept in a clean, dry cloth until tested. The part of the sample to be immersed in the test solution shall not be handled. Care shall be taken to avoid abrasion by the cut ends.

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee B-1 on Copper Wire.

(B) Method of Testing.

Immersion of Samples.

6. (*a*) A length of at least 4½ in. of the cleaned samples shall be immersed, in accordance with the following cycles, in test solutions maintained at a temperature between 15.5 and 21° C. (60 and 70° F.):

First: Immerse for 1 minute in HCl solution as hereinafter defined. Wash and wipe dry.

Second: Immerse for 30 seconds in sodium-polysulfide solution as hereinafter defined. Wash and wipe dry.

Third: Immerse for 1 minute in HCl solution. Wash and wipe dry.

Fourth: Immerse for 30 seconds in sodium-polysulfide solution. Wash and wipe dry.

(*b*) After each immersion the samples shall be immediately and thoroughly washed in clean water and wiped dry with a clean, soft cloth.

Examination of Samples.

7. After the above-described operations, the samples shall be examined in order to ascertain if copper exposed through openings in the tin coating has been blackened by the action of the sodium polysulfide. The sample shall be considered to have failed if by such blackening exposed copper is revealed. No attention shall be paid to blackening within ½ in. of the cut end.

Mechanical Test for Adhesion.

8. A mechanical test for adhesion of tinning may be made by bending the wire around a rod having a diameter equal to four times the diameter of the wire, and dipping the bent portion of the wire in the sodium-polysulfide solution only, for 30 seconds. Any cracking or parting of the coating will be shown by blackening of the copper. Such cracking or parting of the coating will be a cause for rejection.

(C) Testing Solution.

Hydrochloric-Acid Solution.

9. (*a*) The hydrochloric-acid solution, specific gravity 1.088, shall be made in the following manner: Commercial HCl, sp. gr. 1.12, shall be diluted with distilled water to a specific gravity of 1.088 measured at 15.5° C. (60° F.).

(*b*) A portion of HCl solution having a volume of 180 cc. shall be considered exhausted when there have been immersed in it for two cycles the number of test samples of any size as indicated in the following table:

DIAMETER, IN.	MAXIMUM NUMBER TO BE TESTED FOR TWO CYCLES IN 180 CC. OF ACID SOLUTION.
0.460 to 0.141	2
0.140 to 0.086	4
0.085 to 0.051	6
0.050 to 0.039	10
0.038 to 0.031	12
0.030 to 0.003	14

For wire whose diameter is between listed sizes, the number of cycles shall be the same as for the next larger size indicated.

Sodium-Polysulfide Solution.

10. The sodium-polysulfide test solution, sp. gr. 1.142, shall be made in the following manner: A concentrated solution shall be made by dissolving sodium-sulfide crystals in distilled water until the solution is saturated at about 21° C. (70° F.), adding about 250 g. of flowers of sulfur per liter, and allowing to stand for at least 24 hours.

TABLE I.—TENSILE PROPERTIES.

Diameter, in.	Tensile Strength, max., lb. per sq. in.	Elongation in 10 in., min., per cent.
0.460 to 0.290	36 000	30
0.289 to 0.103	37 000	25
0.102 to 0.021	38 500	20
0.020 to 0.012	39 000	15
0.011 to 0.003	40 000	10

The test solution shall be made by diluting a portion of the concentrated solution with distilled water to a specific gravity of 1.142 at 15.5° C. (60° F.). The sodium-polysulfide test solution should have sufficient strength to blacken thoroughly a piece of clean untinned copper wire in 5 seconds. A portion of test solution used for testing samples will not be considered exhausted until it fails to blacken a piece of clean copper as above described.

PHYSICAL PROPERTIES AND TESTS

(*A*) *Mechanical.*

Tensile Properties.

11. (*a*) The tensile strength and elongation of the tinned copper wire shall conform to the values in Table I.

(*b*) For wire whose nominal diameter is between listed sizes, the requirements shall be those of the next larger size indicated in Table I.

(*B*) *Electrical.*

Resistivity.

12. The resistivity of the wire expressed in pounds per mile-ohm at 20° C. (68° F.) shall not exceed the values in Table II.

PERMISSIBLE VARIATIONS

Permissible Variations.

13. (*a*) The size shall be expressed as the diameter of the wire in decimal fractions of an inch.

(*b*) The permissible variation from nominal diameter shall be:

For wire 0.010 in. or over in diameter, 1 per cent under and 3 per cent over;

For wire under 0.010 in. in diameter, 0.0001 in. under and 0.0003 in. over.

(*c*) For coiled wire, each coil shall be gaged in three places; one near each end, and one approximately at the middle. For

TABLE II.—RESISTIVITY.

Diameter, in.	Resistivity, lb. per mile-ohm at 20° C.
0.460 to 0.290.....	896.15
0.289 to 0.103.....	900.77
0.102 to 0.021.....	910.15
0.020 to 0.012.....	929.52
0.011 to 0.003.....	939.51

spools, approximately 12 ft. shall be reeled off and the wire shall be gaged in six places between the second and twelfth foot from the end.

(*d*) The coil or spool will be rejected if the average gage is not within the limits specified in Paragraph (*b*).

WORKMANSHIP AND FINISH

Workmanship.

14. The tin coating shall consist of a smooth continuous layer, firmly adherent to the surface of the copper.

INSPECTION AND REJECTION

Inspection.

15. The manufacturer shall afford the inspector representing the purchaser, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications.

Rejection.

16. Wire which shows exposed copper by blackening after testing in the sodium-polysulfide solution, as described, or which fails to conform with the other requirements of these specifications, shall be rejected.

EXPLANATORY NOTE.

The coating of tin on copper wire is for the purpose of protecting the copper against the action of the rubber insulation. It is, therefore, necessary that the coating be continuous. The test in the sodium polysulfide is for the purpose of determining whether or not the wire carries a continuous envelope of pure tin.

The thickness of the tin coating is necessarily varied. Under the same conditions of tinning the coating on all sizes of wire, excepting on fine wire, is approximately the same. The coating on fine wire is generally relatively heavier than that on coarse wire. It is not, therefore, correct to apply a larger number of cycles in the test on coarse wire than is applied to fine wire. It is probable that one cycle of the dip test would be sufficient to discover defects in tinned wire, but in order to make certain that no partially covered spots may escape attention, two cycles have been provided for. It has been found that the tin coating on copper wire consists of two parts, an envelope of pure tin on the outside, with an intermediate layer of copper-tin alloy. This tin alloy, as well as the amount of tin present, has an effect on the resistivity of the wire. Since the relative amount of tin coating and alloy is greater on the small wire than it is on the coarser wire, the resistivity of the wire increases as the size decreases. This also accounts for the decrease in elongation due to tinning soft wire.

STANDARD SPECIFICATIONS FOR SOFT RECTANGULAR COPPER WIRE[1]

Serial Designation: B 48 - 27

These specifications are issued under the fixed designation B 48; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1923; ADOPTED IN AMENDED FORM, 1927.

Scope.

1. These specifications cover soft or annealed rectangular copper wire with rounded corners.

MANUFACTURE

Material.

2. The copper shall conform in quality and purity to the requirements of either the Standard Specifications for Lake Copper Wire Bars, Cakes, Slabs, Billets, Ingots, and Ingot Bars (Serial Designation: B 4)[2] or of the Standard Specifications for Electrolytic Copper Wire Bars, Cakes, Slabs, Billets, Ingots, and Ingot Bars (Serial Designation: B 5)[3] of the American Society for Testing Materials.

PHYSICAL PROPERTIES AND TESTS

Physical Tests.

3. The wire shall conform to the following requirements as to tensile properties:

THICKNESS, IN.	MAXIMUM TENSILE STRENGTH, LB. PER SQ. IN.	MINIMUM ELONGATION IN 10 IN., PER CENT
0.003 to 0.010	.....	14
0.011 to 0.020	40 000	20
0.021 to 0.050	38 500	25
0.051 to 0.289	37 000	30
0.290 to 0.500	36 000	33

The elongation shall be measured between bench marks placed upon the wire originally 10 in. apart and the fracture shall be between the bench marks and not closer than 1 in. to either bench mark. If upon testing a sample from any coil or reel, the results do not conform to the specified requirements two additional samples shall be tested and the average of the three tests shall determine acceptance or rejection of the coil or reel.

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee B-1 on Copper Wire.

[2] See p. 515. [3] See p. 520.

4. Electric resistivity (Note 1) shall be determined upon fair samples by resistance measurements at a temperature of 20° C. (68° F.) and shall not exceed 891.58 lb.per mile-ohm. Electric Resistivity.

DIMENSIONS AND PERMISSIBLE VARIATIONS

5. (*a*) The permissible variation in thickness, above or below the specified thickness, for different widths shall not exceed the limits given in the following table (Note 2): Dimensions and Permissible Variations.

Specified Thickness, in.	Permissible Variations		
	½ in. or Less in Width	Over ½ in. to 1 in. in Width	Over 1 in. in Width
0.050 or less	0.001 in.	0.001 in.	0.0015 in.
0.051 to 0.100	0.001 in.	0.001 in.	0.002 in.
0.101 to 0.200	1 per cent	1 per cent	0.0025 in.
0.201 to 0.300	1 per cent	1 per cent	0.003 in.
0.301 to 0.500	0.003 in.	1 per cent	1 per cent
0.501 or over	.....	1 per cent	1 per cent

(*b*) A variation of ±0.003 in. will be permitted in the width of wire 0.300 in. or less in width; wire 0.301 to 1.50 in. in width may vary ±1 per cent; wire greater than 1.50 in. in width shall not vary more than ±0.016 in. from the specified width.

(*c*) Dimensions shall be expressed in decimals of an inch.

(*d*) Rectangular wire shall have edges with corners rounded to a radius as given in the following table:

Thickness, in.	Width, 0 to 0.438 in.	Width, 0.439 to 0.625 in.	Width, 0.626 in. or Over
0.050 or less	Half Round	Half Round	Half Round
0.051 to 0.105	0.025	Half Round	Half Round
0.106 to 0.125	0.031	Half Round	Half Round
0.126 to 0.165	0.031	0.047	0.063
0.166 to 0.225	0.047	0.047	0.063
0.226 to 0.438	0.063	0.063	0.094
0.439 to 0.688	.....	0.094	0.125
0.689 and above	.....	.....	0.188

Each coil shall be gaged at three places, one near each end and one approximately at the middle. From reels, approximately 12 ft. shall be reeled off; the wire shall be gaged in six places between the second and twelfth foot from the end. A coil or reel may be rejected if the average of the measurements obtained is not within the limits specified in Paragraphs (*a*) or (*b*).

FINISH

6. (*a*) The wire shall be free from all imperfections not consistent with the best commercial practice. Finish

(*b*) Necessary brazes shall be made in accordance with the best commercial practice.

(*c*) The copper shall be thoroughly annealed after the last drawing or rolling.

PACKING

Packages.

7. (*a*) Rectangular wire shall be shipped in coils or on reels as agreed upon by the purchaser and the manufacturer (Note 3).

(*b*) The wire shall be packed so as to be properly protected against injury during shipment.

(*c*) Unless otherwise agreed upon, the wire shall be shipped in continuous lengths as follows:

Thickness, in.	Width, in.	Minimum Weight per Length, lb.
Less than 0.025	0.500 or less	5
Less than 0.010	Over 0.500	5
0.010 to 0.019, inclusive	Over 0.500	10
0.025 to 0.034, "	0.500 or less	15
0.020 to 0.094, "	Over 0.500 to 0.750	25
0.020 to 0.094, "	Over 0.750 to 1.00	35
0.020 to 0.094, "	Over 1.00	50
0.035 to 0.094, "	0.500 or less	20
0.095 to 0.300, "	0.500 or less	40
0.301 to 0.500, "	0.500 or less	100
Over 0 094	Over 0.500	100

Density.

8. For the purpose of calculating weights, cross-sections, etc.. the density of copper shall be taken as 8.89 g. per cu. cm. at 20° C, (68° F.) (Note 4).

INSPECTION

Inspection.

9. Test and inspection shall be made at the place of manufacture. The manufacturer shall afford the inspector representing the purchaser all reasonable facilities to enable him to satisfy himself that the material conforms to the requirements of these specifications.

EXPLANATORY NOTES

Soft or annealed copper wire is wire which has been drawn and rolled by customary operations and annealed, and finished by cleaning when necessary to remove scale or oxide. The wire is so soft and ductile that it is easily marred and even stretched by careless handling, hence the necessity for confining specifications and inspection to wire in packages as it leaves the manufacturer, and before being put through processes incident to its use by the purchaser.

NOTE 1.—During the year 1913 the following resistivity was agreed upon internationally as standard for annealed copper:

0.15328 ohm per meter-gram at 20° C.

This resistivity is known as the International Annealed Copper Standard[1] and is equivalent to:

875.20 ohms per mile-pound at 20° C.
0.017241 ohm per meter-millimeter squared at 20° C.
1.7241 microhms per centimeter cubed at 20° C.
0.67879 microhms per inch cubed at 20° C.
10.371 ohms per mil-foot at 20° C.

For reducing the resistance of annealed copper from one temperature to another the following temperature coefficients should be used:

At 0° C., 0.00427; at 15° C., 0.00401; at 20° C., 0.00393; at 25° C., 0.00385.

In case it is desired to express the resistivity of copper in terms of conductivity, the International Annealed Copper Standard at 20° C. should be taken as 100-per-cent conductivity, and in reporting conductivity values this standard should be mentioned. It has been deemed preferable to express the requirements in standard specifications in the terms of quantities directly measurable, rather than by reference to some quantity whose standard value is the subject of agreement only. The use of the arbitrary term "conductivity" has no more warrant than the employment of arbitrary gage numbers. Therefore, in these specifications the requirements are stated as the maximum rejection limits to the resistivity.

For the convenience of those who are accustomed to express resistivity in any one of the several more or less common units, the following table of equivalents has been prepared, giving the resistivity of copper at 20° C.

887.05 lb. per mile-ohm is equal to:
0.15535 ohms per meter-gram,
1.7475 microhms per centimeter-cube,
0.68799 microhms per inch-cube,
10.512 ohms per mil-foot.

891.58 lb. per mile-ohm is equal to:
0.15614 ohms per meter-gram,
1.7564 microhms per centimeter-cube,
0.69150 microhms per inch-cube,
10.565 ohms per mil-foot.

NOTE 2.—The use of arbitrary gage numbers to express dimensions cannot be too strongly condemned. There are many such gages in existence, and confusion is to be expected unless the particular gage to be used is specified. Many of the gages have their dimensions stated in absurd figures, such as 0.090742 in., when it is not practical to measure dimensions in the fourth decimal place by workshop tools. Definite dimensions in measurable units are evidently preferable.

NOTE 3.—Attention is called to the necessity for the purchaser and manufacturer agreeing on the package weights which will be standard under any individual contract.

NOTE 4.—Unit weights were formerly defined in these specifications on the basis of specific gravity of copper. This has been changed to basis of density to agree literally with the definition of the Annealed Copper Standard adopted by the International Electrotechnical Commission.

[1] See U. S. Bureau of Standards *Circular No. 31* for further details.

STANDARD SPECIFICATIONS

FOR

BARE CONCENTRIC-LAY COPPER CABLE: HARD, MEDIUM-HARD, OR SOFT[1]

Serial Designation: B 8 - 27

These specifications are issued under the fixed designation B 8; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ADOPTED, 1916; REVISED, 1921, 1927.

Scope.

1. (*a*) These specifications cover bare concentric-lay cables made from round copper wires laid helically around a central core in one or more layers. (Note 1.)

Classes.

(*b*) The purposes for which the several classes of concentric-lay cables are generally used are as follows:

Class A, for bare, weatherproof, slow-burning, and slow-burning weatherproof cable for aerial use;

Class B, for various insulated cable, such as rubber, paper, varnished cloth, etc.;

Class C, for cable where greater flexibility is required than in Class *B*.

MANUFACTURE

Requirements of Wires.

2. (*a*) The copper wires entering into the construction of standard concentric-lay cable shall, before stranding, meet all the requirements of that one of the Standard Specifications, of the American Society for Testing Materials, for Hard-Drawn Copper Wire (Serial Designation: B 1),[2] Medium Hard-Drawn Copper Wire (Serial Designation: B 2),[3] Soft or Annealed Copper Wire (Serial Designation: B 3),[4] or Tinned Soft Copper Wire for Rubber Insulation (Serial Designation: B 33),[5] which applies.

(*b*) The central core shall be made of wire having the same quality and temper as the concentric layers, unless otherwise especially provided for in separate specifications governing the individual case.

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee B-1 on Copper Wire.

[2] See p. 547. [3] See p. 552. [4] See p. 557. [5] See p. 561.

3. Brazes may be made in the wire when finished and ready for cabling. Such brazes shall be made in accordance with the best commercial practice. No brazes in cable made from hard, or medium hard-drawn copper wire may be closer together than 50 ft. **Brazes.**

4. The pitch of standard cable shall not be less than 12 nor more than 16 diameters of the cable, and the lay may be right or left-handed, unless one direction of lay is specified by the purchaser. **Pitch and Lay.**

PHYSICAL PROPERTIES AND TESTS

5. (*a*) Tests for the physical and electrical properties of the wires composing cables made from hard-drawn or medium hard-drawn wire may be made before but not after stranding. (Note 2.) **Testing.**

(*b*) Tests for the physical and electrical properties of wires composing cables made from annealed copper wire or from tinned soft copper wire may be made on wires removed from the cable in which case the maximum tensile strength permitted shall be increased 5 per cent and the minimum elongation permitted shall be reduced 5 per cent. Care must be taken to avoid mechanical injury of wire removed from cable for the purpose of testing.

(*c*) Experience indicates that the tensile strength of concentric-lay copper cable of standard pitch is at least 90 per cent of the total strength required of the wires forming the cable.

6. For the purpose of calculating weights, cross-sections, etc., the density of copper shall be taken as 8.89 g. per cu. cm. at 20° C. (68° F.) (Note 3.). The resistance and mass of a stranded conductor are greater than in a solid conductor of the same cross-sectional area, depending on the lay (that is, the pitch of the twist of the wires). Two per cent shall be taken as the standard increment of resistance and of mass. In cases where the lay is definitely known, the increment shall be calculated and not assumed. **Weights and Area.**

7. The area of cross-section of the completed cable shall not be more than 2 per cent below the area specified, as determined by weight. **Variation in Area.**

8. The area of cross-section, number and diameter of wires, in standard cable Classes *A*, *B*, and *C*, shall be as specified in Table I. (Note 4.) **Construction.**

PACKING

9. (*a*) Package sizes for cable shall be agreed upon in the placing of individual orders. **Packing and Shipping.**

(*b*) The cable shall be protected against damage in ordinary handling and transportation.

INSPECTION

Inspection. 10. (*a*) All testing and inspection, both of individual wires entering into the construction of the cable, and of the completed cable, shall be made at the place of manufacture. Tests on individual wires shall be made on samples taken before cabling, and not on wires

TABLE I

Area of Cross-Section, circular mils	Approximate A. W. G. or B. & S. Gage Sizes	Class A		Class B		Class C	
		Number of Wires	Diameter of Wires, mils	Number of Wires	Diameter of Wires, mils	Number of Wires	Diameter of Wires, mils
2 000 000	....	91	148.2	127	125.5	169	108.8
1 900 000	....	91	144.5	127	122.3	169	106.0
1 800 000	....	91	140.6	127	119.1	169	103.2
1 700 000	....	91	136.6	127	115.7	169	100.3
1 600 000	....	91	132.6	127	112.2	169	97.3
1 500 000	....	61	156.8	91	128.4	127	108.7
1 400 000	....	61	151.5	91	124.0	127	105.0
1 300 000	....	61	146.0	91	119.5	127	101.2
1 250 000	....	61	143.2	91	117.2	127	99.2
1 200 000	....	61	140.3	91	114.8	127	97.2
1 100 000	....	61	134.3	91	109.9	127	93.1
1 000 000	....	61	128.0	61	128.0	91	104.8
950 000	....	61	124.8	61	124.8	91	102.2
900 000	....	61	121.5	61	121.5	91	99.4
850 000	....	61	118.0	61	118.0	91	96.6
800 000	....	61	114.5	61	114.5	91	93.8
750 000	....	61	110.9	61	110.9	91	90.8
700 000	....	61	107.1	61	107.1	91	87.7
650 000	....	61	103.2	61	103.2	91	84.5
600 000	....	37	127.3	61	99.2	91	81.2
550 000	....	37	121.9	61	95.0	91	77.7
500 000	....	37	116.2	37	116.2	61	90.5
450 000	....	37	110.3	37	110.3	61	85.9
400 000	....	19	145.1	37	104.0	61	81.0
350 000	....	19	135.7	37	97.3	61	75.7
300 000	....	19	125.7	37	90.0	61	70.1
250 000	....	19	114.7	37	82.2	61	64.0
212 000	4/0[a]	7–19	173.9–105.5	19	105.5	37–61	75.6–58.9
168 000	3/0[a]	7–19	155.0–94.0	19	94.0	37–61	67.3–52.5
133 000	2/0	7	138.0	19	83.7	37	60.0
106 000	1/0	7	122.8	19	74.5	37	53.4
83 700	1	7	109.3	19	66.4	37	47.6
66 400	2	7	97.4	7	97.4	19	59.1
52 600	3	7	86.7	7	86.7	19	52.6
41 700	4	7	77.2	7	77.2	19	46.9
33 100	5	7	68.8	7	68.8	19	41.7
26 300	6	7	61.2	7	61.2	19	37.2
20 800	7	7	54.5	7	54.5	19	33.1
16 500	8	7	48.6	7	48.6	19	29.5

[a] Class *A* cable, sizes 4/0 and 3/0, is usually 7-strand when bare and 19-strand when weatherproof, etc.

removed from the completed cable except as provided in Section 5 (*b*).

(*b*) The manufacturer shall afford the inspector representing the purchaser all reasonable facilities to enable him to satisfy himself that the material conforms to the requirements of these specifications.

DEFINITION OF TERMS

11. *Concentric-Lay Cable.*—A single conductor cable composed of a central core surrounded by one or more layers of helically laid wires. **Concentric-Lay Cable.**

12. *Lay.*—The lay of a cable is the length expressed in inches for each complete turn of the wire around the axis, measured along its axis. **Lay.**

13. *Direction of Lay.*—The direction of lay is the lateral direction in which the strands of a cable run over the top of the cable as they recede from an observer looking along the axis of the cable. **Direction of Lay.**

EXPLANATORY NOTES

NOTE 1. *Classes of Cable.*—These specifications have been drawn to cover cables made from hard-drawn, medium hard-drawn, and soft copper wire, since the manufacturing of cables from the various classes of wire is similar, and the physical properties of the cable depend upon, and are usually expressed in, terms of those of the class of wire employed.

NOTE 2. *Physical Properties.*—The accurate testing of cable for its physical properties is practically impossible in commercial laboratories. In order to do this, it is necessary to use long lengths and hold the samples in such a way that the wires shall all be in equal tension. Otherwise the strength will be considerably below the actual strength of the cable. A much more accurate idea of the quality of the cable may be obtained by testing the individual wires before cabling than by attempting tests of the physical properties of the finished cable.

Wires unlaid from cable will manifestly have different physical and electrical properties from those of the wire when prepared for cabling, on account of the deformation brought about by laying and again straightening for test.

NOTE 3. *Unit Weight.*—Unit weights were formerly defined in these specifications on the basis of specific gravity of copper. This has been changed to basis of density to agree literally with the definition of the Annealed Copper Standard adopted by the International Electrotechnical Commission.

NOTE 4. *Stranding Table.*—The stranding table, Table I, covers present practice. Class *A* covers the usual bare and weatherproof construction. Class *B* is the same as adopted by the Standards Committee of the American Institute of Electrical Engineers, and is given in the Bureau of Standards *Circular No. 31*, Table XII.

In Class *C* the figures are those of the Bureau of Standards, *Circular No. 31*, Table XII, with additions to cover well-established practice. There is need for a table to cover extra-flexible stranding from soft wire, but there are differences of opinion in regard to what should become standard practice. The Standards Committee of the A. I. E. E. have this matter under consideration, and it has seemed best not to attempt to include figures for extra-flexible stranding in this specification. The stranding table will necessarily be the subject of revision which will be undertaken in cooperation with the Standards Committee of the A. I. E. E.

STANDARD SPECIFICATIONS FOR ROUND AND GROOVED HARD-DRAWN COPPER TROLLEY WIRE[1]

Serial Designation: B 47 – 27

These specifications are issued under the fixed designation B 47; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1923; ADOPTED IN AMENDED FORM, 1925; REVISED, 1927.

Scope.

1. These specifications cover round and grooved hard-drawn copper trolley wire.

MANUFACTURE

Material.

2. The material used shall be electrolytic or low-resistance lake copper conforming in quality and purity to the requirements of either the Standard Specifications for Electrolytic Copper Wire Bars, Cakes, Slabs, Billets, Ingots and Ingot Bars (Serial Designation: B 5)[2] or of the Standard Specifications for Lake Copper Wire Bars, Cakes, Slabs, Billets, Ingots and Ingot Bars (Serial Designation: B 4)[3] of the American Society for Testing Materials.

PHYSICAL PROPERTIES AND TESTS

(*A*) *Round Wire.*

Tensile Strength and Elongation.

3. (*a*) Round wire shall be so drawn that its tensile strength and elongation shall not be less than the values given in Table I.

TABLE I.—VALUES FOR TENSILE STRENGTH AND ELONGATION OF ROUND WIRE.

DIAMETER, IN.	AREA, CIRCULAR MILS	TENSILE STRENGTH, LB. PER SQ. IN.	ELONGATION IN 10 IN., PER CENT
0.548	300 000	47 000	4.50
0.460	211 600	49 000	3.75
0.410	168 100	51 000	3.25
0.365	133 225	52 800	2.80
0.325	105 625	54 500	2.40

The elongation shall be determined as the permanent increase in length due to the breaking of the wire in tension measured between bench marks placed upon the wire originally 10 in. apart. The

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee B-1 on Copper Wire.

These specifications were prepared jointly by the American Electric Railway Engineering Association and the American Society for Testing Materials.

[2] See page 520. [3] See p. 515.

fracture shall be between the bench marks and not closer than 1 in. to either bench mark.

(*b*) Tests upon a section of wire containing a braze shall show at least 95 per cent of the tensile strength of the unbrazed wire.

Elongation tests shall not be made on test sections including brazes.

Twist Test. 4. For the purpose of determining and developing defects which may be prejudicial to the life of trolley wire, owing to its peculiar service, as compared to that of copper wire for other purposes, round wire shall be subjected to the following twisting test. Three twist tests shall be made upon samples 10 in. in length between the holders of the machine. The twisting machine shall be so constructed that there is a linear motion of the tail stock with respect to the head. The twist shall be applied not faster than 10 turns per minute. All three samples shall be twisted to destruction and shall not reveal under test any seams, pits, slivers, or surface imperfections of sufficient magnitude to indicate inherent defects or imperfections in the wire. At the time of fracture the wire shall be twisting with reasonable uniformity. Wire shall not be considered satisfactory which does not withstand at least nine turns before breaking.

Resistivity. 5. Electric resistivity shall be determined upon fair samples by resistance measurements at a temperature of 20° C. (68° F.). The wire shall not exceed in resistivity 900.77 lb. per mile-ohm.

(*B*) *Grooved Wire.*

Physical Properties and Tests. 6. (*a*) The physical tests for grooved wire shall be made in the same manner as those upon the round wire. The tensile strength of grooved wire shall be at least 95 per cent of that required for round wire of the same nominal cross-sectional area; the elongation shall be the same as that required for round wire of the same nominal cross-sectional area. The twist test shall be omitted.

(*b*) Tests upon a section of wire containing a braze shall show at least 95 per cent of the tensile strength of the unbrazed wire.

Elongation tests shall not be made on test sections including brazes.

Resistivity. 7. The requirements for resistivity of grooved wire shall be the same as those for round wire of the same nominal cross-sectional area.

DIMENSIONS AND PERMISSIBLE VARIATIONS

Density. 8. For the purpose of calculating weights, cross-sections, etc., the density of the copper shall be taken as 8.89 g. per cu. cm. at 20° C. (68° F.).

NOTE.—Unit weights were formerly defined in these specifications on the basis of specific gravity of copper. This has been changed to basis of density to agree literally with the definition of the Annealed Copper Standard adopted by the International Electrotechnical Commission.

(*A*) *Round Wire.*

Dimensions and Permissible Variations.

9. (*a*) The size shall be expressed as the diameter of the wire in decimal fractions of an inch, using not more than three places of decimals, *i. e.*, in mils.

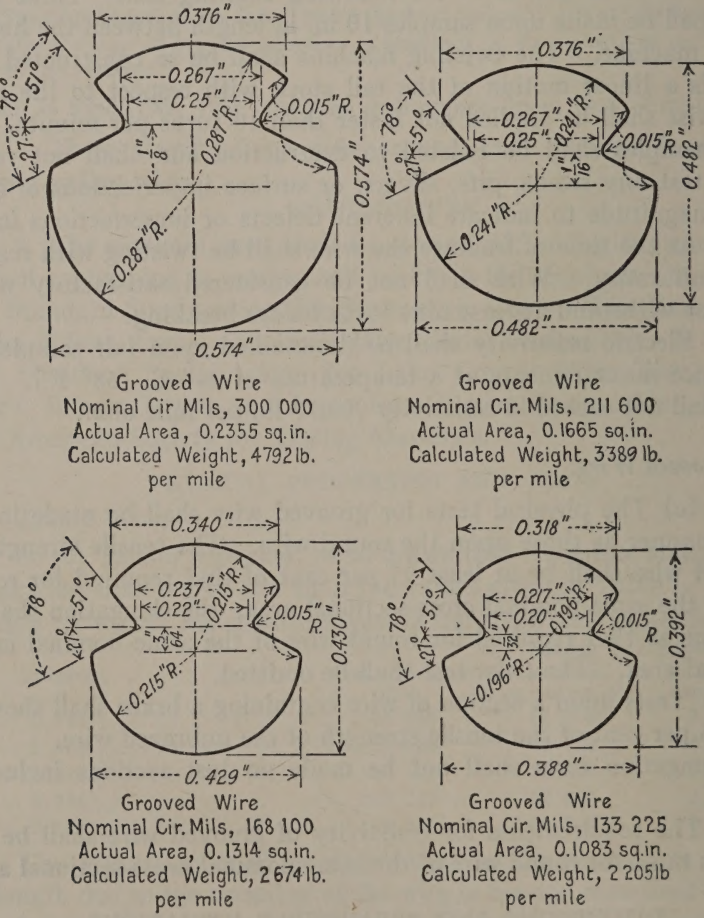


FIG. 1.

(*b*) Wire shall be truly cylindrical in form. The diameter shall not vary more than 1 per cent over or under the diameter specified.

(*B*) *Grooved Wire.*

10. Standard sections of grooved trolley wire shall be those known as the "American Standard Grooved Trolley Wire Sections" (the Standard Design of the American Electric Railway Engineering Association), shown in Fig. 1. Sections.

11. (*a*) Size shall be expressed as the nominal area of cross-section in circular mils, the standard sizes being as follows: Dimensions and Permissible Variations.

NOMINAL AREA, CIRCULAR MILS	ACTUAL AREA, SQ. IN.	CALCULATED WEIGHT BASED ON ACTUAL AREA, LB. PER MILE
300 000	0.2355	4792
211 600	0.1665	3389
168 100	0.1314	2674
133 225	0.1083	2205

(*b*) The weight of grooved trolley wire shall not vary more than 4 per cent over or under the weights specified in Paragraph (*a*).

FINISH

12. (*a*) The wire shall be of uniform size, shape, and quality throughout, and shall be free from all scale, flaws, splits and scratches not consistent with the best commercial practice. Finish.

(*b*) Necessary brazes in trolley wire shall be made in accordance with the best commercial practice.

PACKING

13. All wire shall be shipped on substantial reels, suitable for the weight of the wire handled, and shall be well protected from injury. If reels are to be lagged, it shall be so specified by the purchaser. Packing and Shipping.

The ends shall be securely fastened to the sides of the reel with no less than six staples. The staples shall be at least 2 in. long and made from not less than 0.145-in. diameter wire. Care must be exercised in stapling not to damage the surface of the exposed layer of wire. All reels shall have the arbor holes reinforced with steel plates. Reels shall be marked legibly and indelibly with a serial number, size, kind, length and weight of wire, and such other information as is desired by the purchaser. The length or weight of wire to be wound upon reels shall be agreed upon in placing individual orders.

INSPECTION AND REJECTION

14. All tests governing the acceptance or rejection of the wire, unless otherwise specified, shall be made at the place of manufacture with apparatus furnished by the manufacturer and in the presence Inspection.

of the purchaser, or his representative, who shall be furnished a copy of the tests. Every facility shall be given the purchaser, or his representative, to satisfy him as to the reliability of the results before the wire is delivered. If the purchaser waives inspection, and if he so elects at that time, he shall be furnished with a certified copy of tests made by the manufacturer.

Rejection.

15. Any reel of wire which fails to meet the requirements hereinbefore specified may be rejected. Failure of 30 per cent of the number of reels ready for inspection at one time shall be deemed sufficient cause for the rejection of the whole lot.

STANDARD SPECIFICATIONS
FOR
THE ALLOY: COPPER, 88 PER CENT; TIN, 10 PER CENT; ZINC, 2 PER CENT[1]

Serial Designation: B 10 – 18

These specifications are issued under the fixed designation B 10; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1915; ADOPTED, 1918.

Scope.

1. (*a*) These specifications cover the alloy known commercially as government bronze, admiralty gun-metal, gun-metal, or 88–10–2 mixture, when used in castings.

(*b*) It is recommended that this alloy shall not be used where castings are subjected to a temperature exceeding 260° C. (500° F.).

MANUFACTURE

Process.

2. The alloy may be made by any approved method.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

3. The alloy shall conform to the following requirements as to chemical composition:

Copper	86–89 per cent.
Tin	8–11 "
Zinc	1– 3 "

Chemical Analysis.

4. An analysis of each melt shall be made by the manufacturer. The chemical composition thus determined shall be reported to the purchaser or his representative and shall conform to the requirements specified in Section 3.

Sampling.

5. (*a*) The sample for chemical analysis may be taken either by sawing, drilling or milling the casting or tension test specimen and shall represent the average cross-section of the piece.

(*b*) The saw, drill, cutter or other tool used shall be thoroughly cleaned. No lubricant shall be used in the operation,

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee B-2 on Non-Ferrous Metals and Alloys.

and the saw dust or metal chips shall be carefully treated with a magnet to remove any particles of iron derived from the tools.

PHYSICAL PROPERTIES AND TESTS

Tension Tests.

6. The alloy shall conform to the following minimum requirements as to tensile properties:

Tensile strength, lb. per sq. in.	30 000
Elongation in 2 in., per cent	14

Test Specimens.

7. (*a*) Two test bars of the form and dimensions shown in Fig. 1 shall be an integral part of large castings, or cast separately in the case of small castings to represent a lot or melt

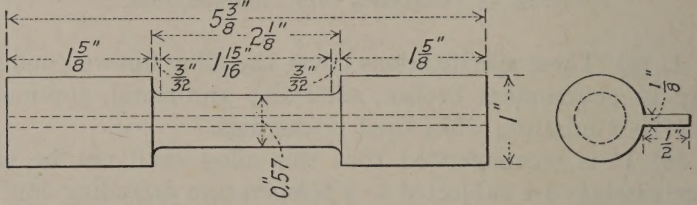


FIG. 1.

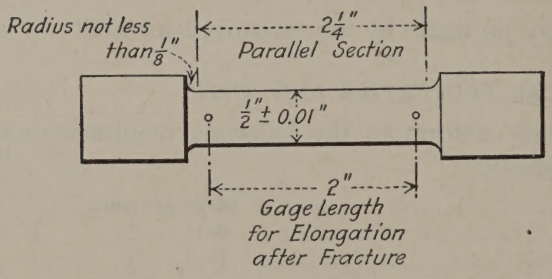

Radius not less than 1/8"
2 1/4"
Parallel Section
1/2" ± 0.01"
2"
Gage Length for Elongation after Fracture
Note:-The Gage Length, Parallel Section, and Fillets shall be as Shown, but the Ends may be of any Shape to fit the Holders of the Testing Machine in such a Way that the Load shall be axial.

FIG. 2.

and shall be molded in a manner similar to the castings which they represent. If the castings are heat-treated, the test bars representing such castings shall be similarly heat-treated.

(*b*) The manufacturer and purchaser shall agree whether test bars can be attached to castings, on the location of the bars on the castings, on the castings to which bars are to be attached, and on the method of casting unattached bars. Unless otherwise agreed upon, the minimum lot shall be considered as 500 lb.

(*c*) Tension test specimens, turned from the test bar shown in Fig. 1, shall conform to the dimensions shown in Fig. 2. The

ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial.

8. (*a*) Two tension tests shall be made from each lot or melt. Number of Tests.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded; in which case the manufacturer and the purchaser or his representative shall agree upon the selection of another specimen in its stead.

INSPECTION AND REJECTION

9. (*a*) Inspection may be made at the manufacturer's works where castings are made, or at the point at which they are received, at the option of the purchaser. Inspection.

(*b*) If the purchaser elects to have inspection made at the manufacturer's works, the inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

10. Castings which show injurious defects revealed by machining operations subsequent to acceptance may be rejected, and, if rejected, shall be replaced by the manufacturer free of cost to the purchaser. The full weight of the original material rejected shall be returned to the manufacturer. Rejection.

STANDARD SPECIFICATIONS FOR BRASS INGOT METAL, GRADED AND UNGRADED, FOR SAND CASTINGS[1]

Serial Designation: B 30 – 22

These specifications are issued under the fixed designation B 30; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1919; ADOPTED IN AMENDED FORM, 1922.

These specifications were approved July 19, 1924, as "Tentative American Standard" by the American Engineering Standards Committee.

Scope.

1. These specifications cover brass ingot metal for sand castings, known commercially as red and yellow brass ingot, made wholly or partly from scrap materials. Seven typical alloys are specified and are designated Grades Nos. 1 to 7, in accordance with their decreasing copper content as specified in Section 3. These specifications also cover brass ingot metal which has no grade limit, designated as ungraded material such as a specific lot of ingots having a stated composition suitable for the buyers' needs.

MANUFACTURE

Quality.

2. The manufacturer shall use care to have each lot of ingot metal as uniform in quality as possible.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

3. Individual ingots of any lot shall not show an extreme variation between the high and low copper percentages of more than 2.5 per cent and between the high and low percentages of the other main constituents, except zinc, of more than 1.5 per cent. The graded alloys shall conform to the following requirements as to chemical composition, within the limits specified in Section 4:

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee B-2 on Non-Ferrous Metals and Alloys.

Alloy, Grade No.	Copper, per cent.	Tin, per cent.	Lead, per cent.	Zinc, per cent.	Impurities, maximum, per cent.				
					Iron.	Antimony.	Aluminum.	Sulfur.	Phosphorus.
1.....	87	8	2[a]	3	0.25	0.25	none	0.05	0.05
2.....	85	5	5	5	0.35	0.25	none	0.05	0.05
3.....	83	4	6	7	0.35	0.25	none	0.05	0.05
4.....	77	3	10	10	0.40	0.35	none	0.05	0.05
5.....	76	2	6	16	0.40	0.25	none	0.05	0.05
6.....	65	1[a]	2	33	0.50	0.20	none[1]	0.05	0.02
7.....	60	1½[a]	3	37	1.00	0.20	none[1]	0.05	0.02

[a] Maximum.

[1] See Appendix.

Permissible Variations.

4. The following permissible variations in the percentages of the desired elements specified in Section 3 will be allowed, but shall not apply to the maximum percentages of impurities specified:

PERCENTAGE OF ELEMENT SPECIFIED.	PERMISSIBLE VARIATIONS OVER AND UNDER THE SPECIFIED VALUE, UNITS OF PER CENT.
Not over 5 per cent	0.50
Over 5 to 15 per cent, incl	0.75
Over 15 per cent	1.00

Samples for Chemical Analysis.

5. (*a*) Ten ingots shall be selected by the inspector to represent 40,000 lb. and five ingots for less than carload lots.

(*b*) The samples for chemical analysis may be taken either by sawing, drilling or milling the ingots and shall represent the average cross-section.

(*c*) The saw, drill, cutter or other tool used shall be thoroughly cleaned. No lubricant shall be used in the operation, and the sawings or metal chips shall be carefully treated with a magnet to remove any particles of steel introduced in taking the sample.

Methods of Chemical Analysis.

6. The chemical analysis shall be made in accordance with the Standard Methods of Chemical Analysis of Brass Ingots and Sand Castings (Serial Designation: B 45) of the American Society for Testing Materials.[1]

MARKING

Marking.

7. The designating mark of the manufacturer, the proper lot number, and the numerical designation of the grade supplied shall be marked on each ingot for identification.

[1] See p. 724.

INSPECTION AND REJECTION

Inspection.

8. (*a*) Inspection may be made at the manufacturer's works where the ingots are made, or at the point at which they are received, at the option of the purchaser.

(*b*) If the purchaser elects to have inspection made at the manufacturer's works, the inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection.

9. If the test ingots selected to represent a lot fail to conform to the requirements specified in Sections 3 and 4, all ingots in such lot will be rejected.

CLAIMS

Claims.

10. Claims, to be considered, shall be made in writing within thirty days of receipt of material at the purchaser's plant, and the results of the purchaser's tests shall be given. The shipper shall within one week of receipt of such claim, either agree to satisfy the claim or send a representative to the purchaser's plant to resample the shipment, as specified in Section 5. Samples so taken shall be sealed and submitted to a mutually agreeable umpire, whose determination shall be final.

Settlement of Claims.

11. The expense of umpire analysis shall be paid by the loser or divided in proportion to the concession made in case of a compromise. In case of rejection being established, the damages shall be limited to the payment of freight both ways by the manufacturer for the substitution of an equivalent weight of ingot metal meeting these specifications.

APPENDIX.

The data in the following table do not constitute a part of these specifications. They are given merely to indicate to the purchaser the physical properties of the various alloys specified which can be expected of carefully manufactured alloys of the formulas indicated, and to constitute a guide to the purchaser in selecting the grade best suited for meeting the service condition for which the ingot metal is to be used.

TABLE SHOWING PHYSICAL PROPERTIES OF BRASS INGOT METAL ALLOYS.

Alloy, Grade No.	DESIRED COMPOSITION.				Tensile Strength, lb. per sq. in.[1]	Elongation, in 2 in., per cent.[1]	Reduction of Area, per cent.[1]	Brinell Hardness (500 kg. for 30 sec.).	Shrinkage, in. per ft.	Weight, lb. per cu. in.
	Copper, per cent.	Tin, per cent.	Lead, per cent.	Zinc, per cent.						
1.....	87	8	2	3	30–36 000	25–30	25–30	.....	0.125	0.31
2.....	85	5	5	5	27–33 000	16–20	15–20	50–60	0.14	0.31
3.....	83	4	6	7	28–33 000	15–20	20–26	55–60	0.125	0.31
4.....	77	3	10	10	23–28 000	10–15	10–15	50–55	0.125	0.32
5.....	76	2	6	16	25–30 000	20–30	20–30	43–48	0.18	0.31
6.....	65	...	2	33	25–30 000	20–30	25–35	37–42	0.18	0.30
7.....	60	...	3	37	30–45 000	15–25	20–30	43–48	0.20	0.29

[1] The tension tests were made on "sand cast-to-size" test specimens.

Grade No.	Example of Uses.	Foundry Manipulation.	Characteristics.
1.....	High grade steam metal.....	Easily handled.....	Machines well.
2.....	High grade red brass for general service.....	Easily handled.....	Machines more readily than No 1.
3.....	Medium grade red brass for general service	Easily handled.....	Machines more readily than No. 1.
4.....	Valves and fittings for low pressures.....	Not difficult.....	Machines very easily.
5.....	Reddish yellow alloy, for air, gas and water fittings.	Not difficult.....	Machines very easily.
6	Yellow brass for general service.....	Difficult. Aluminum up to 0.3 per cent improves casting properties, but increases shrinkage.	Machines poorly. Not suitable for bearings or water pressure fittings.
7	Plumbers' flanges, scupper pipes, etc.....	Very difficult. Aluminum up to 0.3 per cent improves casting properties, but increases shrinkage.	Hard to machine. Not suitable for bearings or water pressure fittings.

STANDARD SPECIFICATIONS
FOR
BRONZE BEARING METAL IN INGOT FORM[1]

Serial Designation: B 31 – 21

These specifications are issued under the fixed designation B 31; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1919; ADOPTED, 1921.

Scope.

1. These specifications cover copper- tin- lead alloys in ingot form, known commercially as "bronze bearing metal," made wholly or partly from scrap materials. Six typical alloys are specified and are designated as Grades Nos. 1 to 6, in accordance with their decreasing copper content as specified in Section 3.

MANUFACTURE

Quality.

2. The manufacturer shall use care to have each lot of bronze bearing metal as uniform in quality as possible.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

3. The alloys shall conform to the following requirements as to chemical composition, within the limits specified in Section 4:

Alloy, Grade No.	Copper, per cent.	Tin, per cent.	Lead, per cent.	Zinc, max., per cent.	Phosphorus, per cent.	Sulfur, max., per cent.	Iron, max., per cent.	Antimony, max., per cent.	Aluminum, per cent.	Total Impurities, max., per cent.
1.....	85	10	5	0.25	0.70[a]	0.05	0.25	0.50	none	0.50
2.....	80	10	10	0.50	0.70[a]	0.05	0.25	0.50	none	0.75
3.....	80	10	10	2.00	0.05[b]	0.05	0.25	0.50	none	2.50
4.....	77	8	15	0.50	0.25[b]	0.05	0.25	0.50	none	0.75
5.....	73	7	20	0.50	0.05[b]	0.05	0.25	0.50	none	1.00
6.....	70	5	25	0.50	none	0.05	0.25	0.50	none	1.00

[a] Minimum. [b] Maximum.

Permissible Variations.

4. The following permissible variations in the percentages of the desired elements specified in Section 3 will be allowed, but

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee B-2 on Non-Ferrous Metals and Alloys.

shall not apply to the maximum percentages of impurities specified:

PERCENTAGE OF ELEMENT SPECIFIED.	PERMISSIBLE VARIATIONS OVER AND UNDER THE SPECIFIED VALUE, UNITS OF PER CENT.
Not over 5 per cent	0.50
Over 5 to 10 per cent, incl	0.75
Over 10 per cent	1.50

Samples for Chemical Analysis.

5. (*a*) Three ingots shall be selected by the inspector to represent 10,000 lb. of ingot or fraction thereof.

(*b*) The samples for chemical analysis may be taken either by sawing, drilling or milling the ingots and shall represent the average cross-section.

(*c*) The saw, drill, cutter or other tool used shall be thoroughly cleaned. No lubricant shall be used in the operation, and the sawings or metal chips shall be carefully treated with a magnet to remove any particles of steel introduced in taking the sample.

MARKING

Marking.

6. The designating mark of the manufacturer, the proper lot number, and the numerical designation of the grade supplied shall be marked on each ingot for identification.

INSPECTION AND REJECTION

Inspection.

7. (*a*) Inspection may be made at the manufacturer's works where the ingots are made, or at the point at which they are received, at the option of the purchaser.

(*b*) If the purchaser elects to have inspection made at the manufacturer's works, the inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection.

8. If the test ingots selected to represent a lot fail to conform to the requirements specified in Sections 3 and 4, all ingots in such lot will be rejected.

CLAIMS

Claims. 9. Claims, to be considered, shall be made in writing within thirty days after receipt of material at the purchaser's plant, and the results of the purchaser's tests shall be given. The shipper shall within one week of receipt of such claim, either agree to satisfy the claim or send a representative to the purchaser's plant to resample the shipment, as specified in Section 5. Samples so taken shall be sealed and submitted to a mutually agreeable umpire, whose determination shall be final.

Settlement of Claims. 10. The expense of umpire analysis shall be paid by the loser or divided in proportion to the concession made in case of a compromise. In case of rejection being established, the damages shall be limited to the payment of freight both ways by the manufacturer for the substitution of an equivalent weight of bronze bearing metal meeting these specifications.

APPENDIX.

The data in the following table do not constitute a part of these specifications. They are given merely to indicate to the purchaser the physical properties of the various alloys specified which can be expected of carefully manufactured alloys of the formulas indicated, and to constitute a guide to the purchaser in selecting the grade best suited for meeting the service condition for which the bronze bearing metal is to be used.

TABLE SHOWING PHYSICAL PROPERTIES OF BRONZE BEARING METAL ALLOYS.

Alloy, Grade No.	Desired Composition.			Ultimate Tensile Strength, lb. per sq. in.[1]	Elongation, in 2 in., per cent.[1]	Brinell Hardness (500 kg. for 30 sec.).	Shrinkage, in. per ft.	Weight, lb. per cu. in.	Compression Deformation Limit, lb. per sq. in.[2]
	Copper, per cent.	Tin, per cent.	Lead, per cent.						
1	85	10	5	28 000	12.5	60	0.25	0.31	18 000
2	80	10	10	25 000	8	55	0.25	0.31	15 000
3	80	10	10	22 000	8	50	0.25	0.32	12 500
4	77	8	15	20 000	10	48	0.25	0.33	12 000
5[a]	73	7	20	18 000	7	45	0.25	0.33	11 000
6[a]	70	5	25	15 000	5	40	0.25	0.33	10 000

[a] More difficult to handle in the foundry than the other grades on account of the segregation of lead. Can be improved by the addition of 1 per cent of nickel.

[1] The tension tests were made on "sand cast-to-size" test specimens.

[2] The compression tests were made on machined test specimens (sand castings) of 1 sq. in. sectional area, 1 in. high. The compression deformation limit is taken as the load producing a compression in the specimen of 0.001 in.

At the request of Committee B-2 on Non-Ferrous Metals and Alloys, Committee E-1 on Methods of Testing is giving consideration to revising the dimensions of compression test specimens and the method of determining the so-called "compression deformation limit." The revision of the values in this column, on the basis of cylindrical specimens 1 sq. in. in sectional area and 3 in. high is contemplated. A revision of the methods of determining compression deformation limit is also under consideration.

STANDARD SPECIFICATIONS
FOR
BRONZE BEARING METALS FOR TURNTABLES AND MOVABLE RAILROAD BRIDGES[1]

Serial Designation: B 22 – 21

These specifications are issued under the fixed designation B 22; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1918; ADOPTED, 1921.

Scope.

1. (*a*) These specifications cover four classes of bronze bearing metals for turntables and movable railroad bridges.

(*b*) The purposes for which these classes are frequently used are as follows:

Class A, for contact with hardened steel disks under pressures over 1500 lb. per sq. in., for example, bearing metals, used in turntables and center-bearing swing bridges;

Class B, for contact with soft steel at low speeds under pressures not over 1500 lb. per sq. in., for example, trunnions and journals of bascule and lift bridges;

Class C, for ordinary machinery bearings;

Class D, for gears, worm wheels, nuts and similar parts which are subjected to other than compressive stresses.

MANUFACTURE

Process.

2. (*a*) The bronze shall be a homogeneous alloy of copper and tin. The copper shall conform to the requirements of the Standard Specifications for Electrolytic Copper Wire Bars, Cakes, Slabs, Billets, Ingots, and Ingot Bars (Serial Designation: B 5),[2] or the Standard Specifications for Lake Copper Wire Bars, Cakes, Slabs, Billets, Ingots, and Ingot Bars, "high-resistance" grade (Serial Designation: B 4),[3] of the American Society for Testing Materials. The bronze shall be made from new metal, except that scrap of known composition produced by the foundry at which the bronze is cast may be used.

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee B-2 on Non-Ferrous Metals and Alloys.

[2] See p. 520. [3] See p. 515.

(*b*) Care shall be exercised that the metal is not overheated and that the temperature at pouring and the conditions of cooling are such as will be most likely to secure dense castings.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

3. The bronze shall conform to the following requirements as to chemical composition:

Elements Considered.	Class.			
	A	B	C	D
Copper, per cent	Remainder	Remainder	not over 82	not over 89
Tin, max., per cent	20	17	11	11
Lead, max., per cent	....	....	11	....
Zinc, max., per cent	....	....	....	2.25
Iron, max., per cent	....	....	....	0.2
Phosphorus, per cent	not over 1.0	not over 1.0	0.7 - 1.0	not over 0.25
Other elements, max., per cent	0.5	0.5	0.5	0.5

Chemical Analyses.

4. (*a*) An analysis of each melt may be made at the option of the purchaser and at the purchaser's expense. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 3.[1]

(*b*) The compression test coupon shall be used for analysis.

PHYSICAL PROPERTIES AND TESTS

Compression and Tension Tests.

5. (*a*) The bronze shall conform to the following requirements as to compressive and tensile properties:

Properties Considered.	Class.			
	A	B	C	D
Compression.				
Deformation limit, min., lb. per sq. in.	24 000	18 000	....	....
Permanent set in 1 in. under 100 000 lb. per sq. in., in	0.06 - 0.12	0.10 - 0.20	....	....
Tension.				
Yield point, min., lb. per sq. in.	....	....	....	To be recorded
Tensile strength, min., lb. per sq. in.	....	....	....	33 000
Elongation in 2 in., min., per cent	....	....	....	14

[1] Material with a range of composition differing from that specified in Section 3, or containing elements not specified, may be used, provided the manufacturer shall submit in writing previous to the execution of the contract the range of composition of the material he proposes to use, and provided this range of composition shall be accepted by the purchaser.

(*b*) The deformation limit in compression shall be determined as that load which produces a permanent set of 0.001 in. in the compression test specimen described in Section 6 (*b*).[1]

(*c*) The yield point in tension shall be determined as the stress producing an elongation under load of 0.5 per cent, that is, 0.01 in. in a gage length of 2 in.

6. (*a*) A test bar of the form and dimensions shown in Fig. 1, to be used for the tension test specimen, and a suitable

Test Specimens.

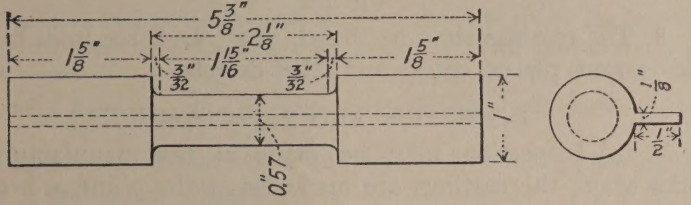


FIG. 1.

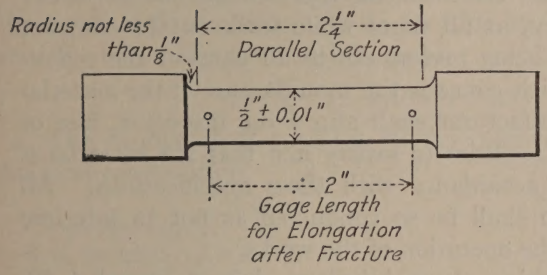

Radius not less than 1/8"
2 1/4"
Parallel Section
1/2" ± 0.01"
2"
Gage Length for Elongation after Fracture
Note:-The Gage Length, Parallel Section, and Fillets shall be as Shown, but the Ends may be of any Shape to fit the Holders of the Testing Machine in such a Way that the Load shall be axial

FIG. 2.

test bar for the compression test specimen, shall be an integral part of the casting, and shall be fed and cooled under the same conditions as the castings.

(*b*) Compression test specimens shall be cylinders 1 sq. in. in cross-sectional area and 1 in. high.[1]

(*c*) Tension test specimens, turned from the test bar shown in Fig. 1, shall conform to the dimensions shown in Fig. 2. The ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial.

[1] The matters of revising the dimensions of compression test specimens and the method of determining the so-called "deformation limit" are under consideration by Committee E-1 on Methods of Testing. Tests are being made on cylindrical specimens 1 sq. in. in cross-sectional area and 3 in. high. Committee B-2 on Non-Ferrous Metals and Alloys feels that these specifications with the present compression tests as specified may be satisfactorily used until better compression test specimens are available.—ED.

Number of Tests.

7. (*a*) One compression test shall be made from each melt for Class A and B castings; and one tension test from each melt for Class D castings. For castings of any grade weighing over 100 lb. finished, the specified tests shall be made for each casting.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded; in which case the manufacturer and the purchaser or his representative shall agree upon the selection of another specimen in its stead.

FINISH

Finish.

8. The castings shall be sound, clean, and free from blowholes, porous places, cracks and other defects.

INSPECTION AND REJECTION

Inspection.

9. (*a*) Inspection may be made at the manufacturer's works where the castings are made, or at the point at which they are received, at the option of the purchaser.

(*b*) If the purchaser elects to have inspection made at the manufacturer's works, the inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection.

10. Castings which show injurious defects revealed by machining operations subsequent to acceptance may be rejected, and if rejected, shall be replaced by the manufacturer free of cost to the purchaser. The full weight of the original material rejected shall be returned to the manufacturer.

STANDARD SPECIFICATIONS
FOR
MANGANESE-BRONZE INGOTS FOR SAND CASTINGS[1]

Serial Designation: B 7 - 27

These specifications are issued under the fixed designation B 7; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ADOPTED, 1911; REVISED, 1914; REISSUED AS TENTATIVE, 1924; ADOPTED, 1927.

Scope.

1. These specifications cover the copper-zinc alloy known commercially as manganese bronze.

MANUFACTURE

Size of Ingots.

2. The bronze shall be cast in the form of ingots having notched flat bottoms, approximately 3 by 2¾ in. wide by 12 in. long, properly tapered to strip easily from an iron mold.

CHEMICAL PROPERTIES[2]

Chemical Composition.

3. The bronze shall conform to the following requirements as to chemical composition:

	MAXIMUM	MINIMUM
Copper, per cent	60	55
Zinc, per cent	42	38
Tin, per cent	1.5	0.0
Manganese, per cent	3.5	0.0
Aluminum, per cent	1.5	0.0
Iron, per cent	2.	0.0
Lead, per cent	0.2	0.0

PHYSICAL PROPERTIES AND TESTS

Tension Tests.

4. The bronze shall conform to the following minimum requirements as to tensile properties:

Tensile strength	70 000 lb. per sq. in.
Elongation in 2 in.	30 per cent

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee B-2 on Non-Ferrous Metals and Alloys.

[2] Because of claims made of the improved qualities of manganese bronze made from virgin metal (copper conforming to the Standard Specifications for Electrolytic Copper Wire Bars, Cakes, Slabs, Billets, Ingots and Ingot Bars (Serial Designation: B 5) and zinc conforming to the requirements of Grade 2 or better of the Standard Specifications for Spelter (Serial Designation: B 6) of the American Society for Testing Materials, see pp. 520-526) the buyer may, at his option, elect when contracting that these materials only be used.

Tension Test Specimens.

5. (*a*) The tension test specimen shall be cut from one corner near the bottom of the test ingot.

(*b*) The specimen shall conform to the dimensions shown in Fig. 1.

Number of Tests.

6. (*a*) One test ingot shall be selected by the inspector to represent 10,000 lb. of ingots or fraction thereof.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded, in which case two additional test specimens may be selected by the inspector from the same lot, and tested to represent the lot.

MARKING

Marking.

7. Each ingot shall be stamped with its proper heat or charge number.

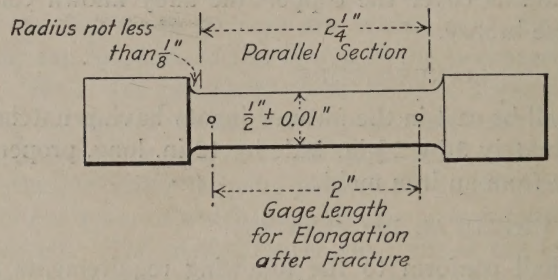

Radius not less than 1/8"
2 1/4"
Parallel Section
1/2" ± 0.01"
2"
Gage Length for Elongation after Fracture
Note:-The Gage Length, Parallel Section, and Fillets shall be as Shown, but the Ends may be of any Shape to fit the Holders of the Testing Machine in such a Way that the Load shall be axial.

FIG. 1

INSPECTION AND REJECTION

Inspection.

8. (*a*) Inspection may be made at the manufacturer's works where the castings are made or at the point at which they are received, at the option of the purchaser.

(*b*) If the purchaser elects to have inspection made at the manufacturer's works, the inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection.

9. (*a*) If the test ingots selected to represent a lot fail to conform to the requirements specified in Sections 3 or 4, all ingots in such lot will be rejected, irrespective of the heat or heats from which the test ingots are selected.

STANDARD SPECIFICATIONS

FOR

MANGANESE-BRONZE SAND CASTINGS[1]

Serial Designation: B 54 – 27

These specifications are issued under the fixed designation B 54; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1924; ADOPTED, 1927.

Scope.

1. These specifications cover castings made from the copper-zinc alloy known commercially as manganese bronze.

MANUFACTURE

Material.

2. Material used in these castings shall conform to the requirements of the Standard Specifications for Manganese-Bronze Ingots for Sand Castings (Serial Designation: B 7) of the American Society for Testing Materials.[2] At least 35 per cent of the mixture shall consist of ingots manufactured in accordance with the Standard Specifications for Manganese-Bronze Ingots and the remainder shall consist of risers, sprues, and defective castings, accruing from the manufacture of castings in accordance with these specifications. Zinc additions shall be of zinc conforming to the requirements of Grade 2 or better of the Standard Specifications for Spelter (Serial Designation: B 6) of the American Society for Testing Materials.[3]

CHEMICAL PROPERTIES

Chemical Composition.

3. The bronze shall conform to the following requirements as to chemical composition:

	MAXIMUM	MINIMUM
Copper, per cent	60	55
Zinc, per cent	42	38
Tin, per cent	1.5	0.0
Manganese, per cent	3.5	0.0
Aluminum, per cent	1.5	0.0
Iron, per cent	2.	0.0
Lead, per cent	0.4	0.0

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee B-2 on Non-Ferrous Metals and Alloys.

[2] See p. 593. [3] See p. 524.

PHYSICAL PROPERTIES AND TESTS

Tension Tests.

4. The bronze should conform to the following minimum requirements as to tensile properties:

Tensile strength	65,000 lb. per sq. in.
Elongation in 2 in.	25 per cent

Tension Test Specimen.

5. (*a*) The tension test specimen shall be machined from coupons to the dimensions as shown in Fig. 1.

(*b*) The coupon attached to the castings shall be in accordance with Fig. 2, unless special authority to use coupons of other forms and dimensions is obtained from the purchaser.

(*c*) Each casting weighing 250 lb. or more as delivered from the foundry shall have at least two test coupons cast attached.

(*d*) When the castings constituting a heat weigh less than 250 lb. each, one coupon shall be cast attached to the first and one to the last casting poured in each heat.

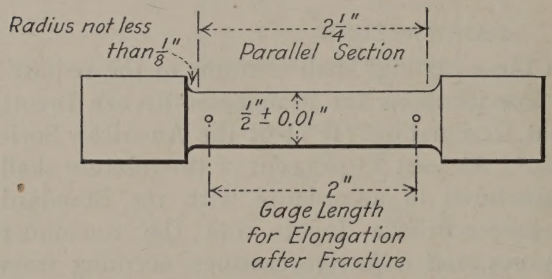

Radius not less than 1/8"
2 1/4"
Parallel Section
1/2" ± 0.01"
2"
Gage Length for Elongation after Fracture
Note:-The Gage Length, Parallel Section, and Fillets shall be as Shown, but the Ends may be of any Shape to fit the Holders of the Testing Machine in such a Way that the Load shall be axial

FIG. 1.—Test Specimen.

(*e*) Castings which are too small to permit the casting of a coupon attached shall, when possible, be represented by coupons cast in the same flask and gated to the castings or runners. One coupon shall be cast gated to the first and one to the last casting poured in the heat.

(*f*) Only in cases when it is impossible to cast coupons in the same flask with small castings shall such coupons be cast separately. In case it is necessary to cast coupons separately, one coupon shall be cast to the first of the heats and one to the last.

(*g*) At least two ounces of drillings from each coupon tested shall be forwarded for chemical analysis.

MARKING

Marking.

6. Each casting shall be clearly stamped with the heat number, and the heat number shall also be stamped on the test coupon representing that heat.

INSPECTION AND REJECTION

7. (*a*) Inspection may be made at the manufacturer's works where the castings are made, or at the point at which they are received, at the option of the purchaser. Inspection.

(*b*) If the purchaser elects to have inspection made at the manufacturer's works, the inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with

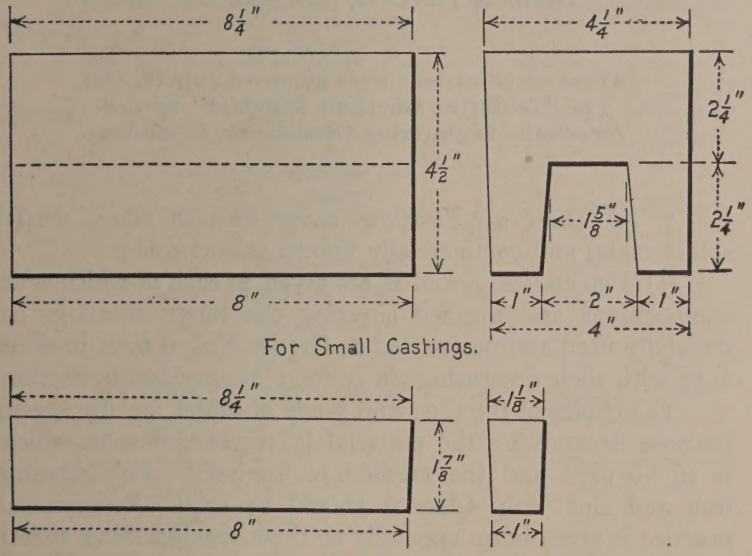


FIG. 2

these specifications. All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

8. (*a*) Any casting may be rejected upon the failure of the test coupon to meet the physical requirements specified or for the noncompliance with the chemical composition. If the physical or chemical tests indicate that the heat of castings represented by its test coupon does not conform to the physical or chemical requirements, or both, the entire heat shall be rejected. Rejection.

(*b*) In case tests on the first test piece do not conform to these specifications, a second test piece shall be tested. If such a test on the second piece is thoroughly satisfactory the castings or heat shall be accepted; if unsatisfactory, the castings or heat shall be rejected.

STANDARD SPECIFICATIONS
FOR
SOLDER METAL[1]

Serial Designation: B 32 – 21

These specifications are issued under the fixed designation B 32; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1919; ADOPTED, 1921.

These specifications were approved July 19, 1924, as "Tentative American Standard" by the American Engineering Standards Committee.

Scope.

1. (*a*) These specifications cover lead-tin alloys used for solder metal and commercially known as soft solder.

(*b*) Two classes, A and B, are given, in each of which several compositions are specified covering the range of alloys commercially used and designated as Grades Nos. 0 to 5, in accordance with their decreasing tin content as specified in Section 4.

The choice of the class and grade of solder for any specified purpose depends on the material in connection with which it is to be used and the method of applying. For galvanized iron and zinc, only Class A should be used. Recommended practice is given in an appendix to these specifications, together with a table showing melting points to constitute a guide to the purchaser in selecting the grade best suited for meeting the conditions required.

MANUFACTURE

Quality.

2. The manufacturer shall use care to have each lot of solder metal as uniform in quality as possible. Each bar, ingot, or other form in which the solder is sold shall be uniform in composition with the entire lot. All grades in Class A shall be made from new or virgin metals. All grades in Class B shall be made from at least one-half new or virgin metals, the balance being recovered or secondary metals.

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee B-2 on Non-Ferrous Metals and Alloys.

3. When specified in bar or ingot form, the sizes or shapes, unless otherwise specified, shall be approximately as follows: **Dimensions.**

		LENGTH, IN.	WIDTH, IN.	THICKNESS, IN.
A.....Bar..	Top.....	13½	¾	⅜
	Bottom.....	13½	⅝	
B.....Ingot	Top.....	5½	2½	1½
	Bottom.....	4½	1½	

CHEMICAL PROPERTIES AND TESTS

4. The alloys shall conform to the following requirements as to chemical composition, within the limits specified in Section 5: **Chemical Composition.**

Grade No.	Tin, per cent.	Lead, Approx., per cent.	Antimony, max., per cent.	Copper, max., per cent.	Zinc and Aluminum, per cent.	Other Impurities,[1] max., per cent.
CLASS A.						
0.....	63.00	37.00	0.12	0.08	none	0.10
1.....	50.00	50.00	0.12	0.08	none	0.10
2.....	45.00	55.00	0.12	0.08	none	0.10
3.....	40.00	60.00	0.12	0.08	none	0.10
4.....	37.50	62.50	0.12	0.08	none	0.10
5.....	33.00	67.00	0.12	0.08	none	0.10
CLASS B.						
1.....	49.25	50.00	0.75	0.15	none	0.10
2.....	43.50	55.00	1.50	0.15	none	0.10
3.....	38.00	60.00	2.00	0.15	none	0.10
4.....	35.50	62.50	2.00	0.15	none	0.10
5.....	31.00	67.00	2.00	0.15	none	0.10

[1] Exclusive of Bismuth.

5. The permissible variation plus or minus in the percentage of tin shall not be over 1 per cent of the tin contents specified in Section 4. **Permissible Variations.**

6. (*a*) Three bars or ingots shall be selected to represent a shipment of less than 1000 lb., five bars or ingots to represent a shipment of over 1000 lb. to 10,000 lb., inclusive, and ten bars or ingots to represent a shipment of over 10,000 lb. to one carload. In case the shipment is in other form, such as wire, wire segments, drops, pigs or slabs, an equivalent amount of **Sample for Chemical Analysis.**

metal representative of the lot shall be taken, but in no case shall less than one whole piece (except wire) represent a shipment.

(*b*) The preferable method of preparing the sample for chemical analysis is to cut exactly in half the bars selected, marking each half and retaining one of each of the half bars to preserve their identity and for check analysis. The remaining half of each bar shall then be remelted in a perfectly clean utensil at a temperature a little above the complete liquation point of the alloy, mixed thoroughly and poured into a cold mold, forming a thin bar approximately $\frac{1}{4}$ in. thick. Saw cuts shall then be made entirely across this bar not more than 1 in. apart and evenly distributed throughout its length.

If it is impracticable to remelt the sample as above, saw cuts shall be made entirely across each piece at several points not more than 1 in. apart and evenly distributed throughout their length. No lubricants shall be used for sawing.

(*c*) Sawings thoroughly mixed shall constitute the sample for chemical analysis.

Methods of Chemical Analysis.

7. The chemical analysis shall be made in accordance with the Standard Methods of Chemical Analysis of Alloys of Lead, Tin, Antimony and Copper (Serial Designation: B 18) of the American Society for Testing Materials.[1]

MARKING

Marking.

8. The name of the manufacturer may be cast, at the option of the purchaser, on each bar or ingot. The numerical designation of the grade supplied shall be stamped or cast on each bar or ingot for identification.

INSPECTION AND REJECTION

Inspection.

9. (*a*) Inspection may be made at the manufacturer's works where the solder metal is made, or at the point at which it is received, at the option of the purchaser.

(*b*) If the purchaser elects to have inspection made at the manufacturer's works, the inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

[1] See p. 691.

10. If the sample selected to represent a lot fails to conform to the requirements specified in Sections 3 and 4, all solder metal in such lot will be rejected. **Rejection.**

CLAIMS

11. Claims, to be considered, shall be made in writing within thirty days of receipt of material at the purchaser's plant, and the results of the purchaser's tests shall be given. The shipper shall within one week of receipt of such claim, either agree to satisfy the claim or send a representative to the purchaser's plant to resample the shipment, as specified in Section 6. Samples so taken shall be sealed and submitted to a mutually agreeable umpire, whose determination shall be final. **Claims.**

12. The expense of umpire analysis shall be paid by the loser, or divided in proportion to the concession made in case of a compromise. In case of rejection being established, the damages shall be limited to the payment of freight both ways by the manufacturer for the substitution of an equivalent weight of solder metal meeting these specifications. **Settlement of Claims.**

APPENDIX.

It is recommended that the grade of solder metal be selected which contains the least amount of tin required to give suitable flowing and adhesive qualities for the work in hand.

TABLE SHOWING MELTING POINTS OF SOLDER METAL.

Grade.	Formula.			Melting Point.		Complete Liquation Point.	
	Tin, per cent.	Lead, per cent.	Antimony, per cent.	Deg. Cent.	Deg. Fahr.	Deg. Cent.	Deg. Fahr.
Tin	100.00	.....	.....	232	449.6	232	449.6
0 A	63.00	37.00	0.12	181	357.8	181	357.8
1 A	50.00	50.00	0.12	181	357.8	213	415.4
1 B	49.25	50.00	0.75	185	365.0	208	397.4
2 A	45.00	55.00	0.12	181	357.8	225	437.0
2 B	43.50	55.00	1.50	188	370.4	220	428.0
3 A	40.00	60.00	0.12	181	357.8	237	458.6
3 B	38.00	60.00	2.00	188	370.4	228	442.4
4 A	37.50	62.50	0.12	181	357.8	241	467.6
4 B	35.50	62.50	2.00	188	370.4	231	411.8
5 A	33.00	67.00	0.12	181	357.8	252	485.6
5 B	31.00	67.00	2.00	188	370.4	235	455.0
Lead	.....	100.00	.....	327	620.6	327	620.6

A table is given showing the melting points of the different grades of solder metal and of tin and lead for comparison. It is to be noted that the alloys are completely solid below the lower point given, designated "melting point", and completely liquid only above the higher point given, designated "complete liquation point." In the range of temperature between these two points the alloys are partly solid and partly liquid. In Grade No. 1 the amount of solid portion is so small in the range given that it is practically unnoticeable. In Grade No. 4 the proportion of solid and fluid metal in the range given makes this alloy suitable for use as wiping solder.

The data in this appendix do not constitute a part of these specifications. They are given merely to indicate to the purchaser the physical properties of the various alloys specified which can be expected of carefully manufactured alloys of the formulas indicated, and to constitute a guide to the purchaser in selecting the grade best suited for meeting the service condition for which the solder metal is to be used.

STANDARD SPECIFICATIONS

FOR

WHITE METAL BEARING ALLOYS[1]

(KNOWN COMMERCIALLY AS "BABBITT METAL")

Serial Designation: B 23 – 26

These specifications are issued under the fixed designation B 23; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1918; ADOPTED, 1926.

Scope.

1. These specifications cover white metal bearing alloys, known commercially as "babbitt metal." Twelve typical babbitt metals are specified, covering the range of alloys commercially used and are designated as Grades Nos. 1 to 12, in accordance with their decreasing tin content as specified in Section 4.

MANUFACTURE

Quality.

2. The manufacturer shall use care to have each lot of babbitt metal as uniform in quality as possible.

Dimensions.

3. The standard bar, unless otherwise specified, shall have the following approximate dimensions:

Top face	$1\frac{1}{4}$ in. wide, $8\frac{1}{2}$ in. long.
Thickness	not over $1\frac{1}{4}$ in.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

4. The alloys shall conform to the following requirements as to chemical composition, within the limits specified in Section 5:

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee B-2 on Non-Ferrous Metals and Alloys.

Alloy Grade No.	Tin, per cent.	Antimony, per cent.	Lead, per cent.	Copper, per cent.	Iron, max., per cent.	Arsenic, max., per cent.	Zinc, per cent.	Aluminum, per cent.
1.....	91	$4\frac{1}{2}$	0.35[a]	$4\frac{1}{2}$	0.08	0.10	none	none
2.....	89	$7\frac{1}{2}$	0.35[a]	$3\frac{1}{2}$	0.08	0.10	none	none
3.....	$83\frac{1}{3}$	$8\frac{1}{3}$	0.35[a]	$8\frac{1}{3}$	0.08	0.10	none	none
4.....	75	12	10	3	0.08	0.15	none	none
5.....	65	15	18	2	0.08	0.15	none	none
6.....	20	15	$63\frac{1}{2}$	$1\frac{1}{2}$	0.08	0.15	none	none
7.....	10	15	75	0.50[a]	....	0.20	none	none
8.....	5	15	80	0.50[a]	....	0.20	none	none
9.....	5	10	85	0.50[a]	....	0.20	none	none
10.....	2	15	83	0.50[a]	....	0.20	none	none
11.....	..	15	85	0.50[a]	....	0.25	none	none
12.....	..	10	90	0.50[a]	....	0.25	none	none

[a] Maximum.

Permissible Variations.

5. The following permissible variations in the percentages of the desired elements specified in Section 4 will be allowed, but shall not apply to the maximum percentages of impurities specified:

Percentage of Element Specified	Permissible Variations Over or Under the Specified Value, Units of Per Cent
Not over 2 per cent	0.25
Over 2 to 5 per cent, incl	0.50
Over 5 to 10 per cent, incl	0.75
Over 10 per cent	1.00

Samples for Chemical Analysis.

6. (*a*) Three bars shall be selected to represent a shipment of less than 1000 lb., five bars to represent a shipment of over 1000 lb. to 10,000 lb., inclusive, and ten bars to represent a shipment of over 10,000 lb. to one carload.

(*b*) Saw cuts shall be made at points in the bars indicated in Fig. 1. No lubricants shall be used for sawing. The sawings shall be carefully treated with a magnet to remove any particles of steel introduced in taking the sample.

(*c*) Sawings thoroughly mixed shall constitute the sample for chemical analysis.

Methods of Chemical Analyses.

7. The chemical analysis shall be made in accordance with the Standard Methods of Chemical Analysis of Alloys of Lead, Tin, Antimony and Copper (Serial Designation: B 18) of the American Society for Testing Materials.[1]

[1] See p. 691.

MARKING

8. The name of the manufacturer shall be cast on each bar. The numerical designation of the grade supplied shall be stamped or cast on each bar for identification. **Marking.**

NOTE.—A preferred arrangement of marking is shown in Fig. 2.

CLAIMS

9. Claims, to be considered, shall be made in writing within thirty days of receipt of material at the purchaser's plant, and **Claims.**

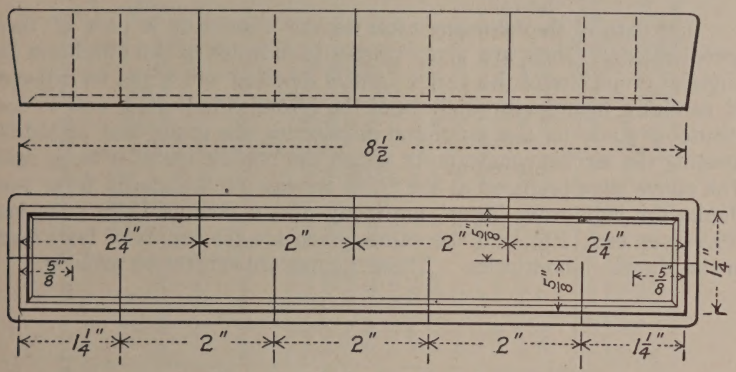


FIG. 1.—Method of Sampling.

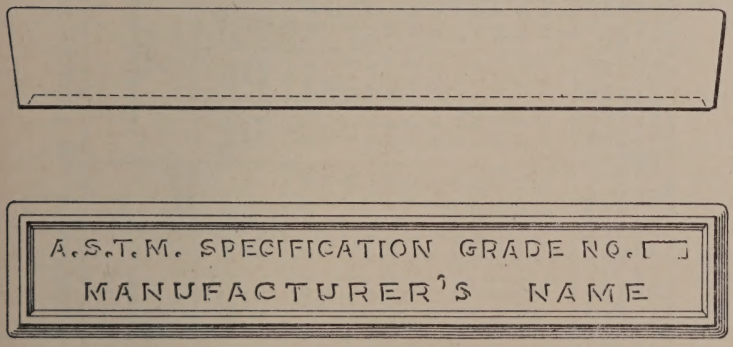


FIG. 2.—Preferred Arrangement of Marking.

the results of the purchaser's tests shall be given. The shipper shall within one week of receipt of such claim, either agree to satisfy the claim or send a representative to the purchaser's plant to resample the shipment, as specified in Section 6. Samples so taken shall be sealed and submitted to a mutually agreeable umpire, whose determination shall be final.

Settlement of Claims.

10. The expense of umpire analysis shall be paid by the loser, or divided in proportion to the concession made in case of a compromise. In case of rejection being established, the damages shall be limited to the payment of freight both ways by the manufacturer for the substitution of an equivalent weight of babbitt metal meeting these specifications.

APPENDIX.

The data in the following table do not constitute a part of these specifications. They are given merely to indicate to the purchaser the physical properties of the various alloys specified which can be expected of carefully manufactured alloys of the formulas indicated, and to constitute a guide to the purchaser in selecting the grade best suited for meeting the service condition for which the babbitt metal is to be used. The alloys were prepared at the U. S. Bureau of Standards from pure Banka tin, high grade "Star" antimony and a commercially pure lead (99.94 per cent Pb), and the values given are the results of tests made in the Bureau laboratories. These figures are subject to revision.

COMPOSITION AND PHYSICAL PROPERTIES[1] OF WHITE METAL BEARING ALLOYS

Alloy Number	Specified Composition of Alloys				Specific Gravity	Compositions of Alloys Tested				Yield Point, lb. per sq. in.[2]		Johnson's Apparent Elastic Limit, lb. per sq. in.[3]		Ultimate Strength, lb. per sq. in.[4]		Brinell Hardness[5]		Melting Point		Temperature of Complete Liquidation		Proper Pouring Temperature	
	Copper, per cent	Tin, per cent	Antimony, per cent	Lead, per cent		Copper, per cent	Tin, per cent	Antimony, per cent	Lead, per cent	20° C.	100°C.	20° C.	100°C.	20° C.	100°C.	20° C.	100°C.	Deg. Fahr.	Deg. Cent.	Deg. Fahr.	Deg. Cent.	Deg. Fahr.	Deg. Cent.
1	4.5	91.0	4.5	....	7.34	4.56	90.9	4.52	none	4400	2650	2450	1050	12850	6950	17.0	8.0	433	223	...	...	825	441
2	3.5	89.0	7.5	....	7.39	3.1	89.2	7.4	0.03	6100	3000	3350	1100	14900	8700	24.5	12.0	466	241	669	354	795	424
3	$8\frac{1}{3}$	$83\frac{1}{3}$	$8\frac{1}{3}$	....	7.46	8.3	83.4	8.2	0.03	6600	3150	5350	1300	17600	9900	27.0	14.5	464	240	792	422	915	491
4	3.0	75.0	12.0	10.0	7.52	3.0	75.0	11.6	10.2	5550	2150	3200	1550	16150	6900	24.5	12.0	363	184	583	306	710	377
5	2.0	65.0	15.0	18.0	7.75	2.0	65.5	14.1	18.2	5050	2150	3750	1500	15050	6750	22.5	10.0	358	181	565	296	690	366
6	1.5	20.0	15.0	63.5	9.33	1.5	19.8	14.6	63.7	3800	2050	3550	1800	14550	8050	21.0	10.5	358	181	531	277	655	346
7	...	10.0	15.0	75.0	9.73	0.11	10.0	14.5	75.0	3550	1600	2500	1350	15650	6150	22.5	10.5	464	240	514	268	640	338
8	...	5.0	15.0	80.0	10.04	0.14	5.2	14.9	79.4	3400	1750	2650	1200	15600	6150	20.0	9.5	459	237	522	272	645	341
9	...	5.0	10.0	85.0	10.24	0.06	5.0	9.9	84.6	3400	1550	2400	950	14700	5850	19.0	8.5	459	237	493	256	620	327
10	...	2.0	15.0	83.0	10.07	0.12	2.05	15.7	82.0	3350	1850	2250	1200	15450	5750	17.5	9.0	468	242	507	264	630	332
11	...	....	15.0	85.0	10.28	0.19	0.09	14.8	84.7	3050	1400	2750	1100	12800	5100	15.0	7.0	471	244	504	262	630	332
12	...	....	10.0	90.0	10.67	0.12	0.11	9.9	89.4	2800	1250	2250	950	12900	5100	14.5	6.5	473	245	498	259	625	329

[1] The compression test specimens were cylinders $1\frac{1}{2}$ in. in length and $\frac{1}{2}$ in. diameter, machined from chill castings 2 in. in length and $\frac{3}{4}$ in. in diameter. The Brinell tests were made on the bottom face of parallel machined specimens cast in a 2-in. diameter by $\frac{5}{8}$-in. deep steel mold at room temperature.

[2] The values for yield point were taken from stress-strain curves at a deformation of 0.125 per cent reduction of gage length.

[3] Johnson's apparent elastic limit is taken as the unit stress at the point where the slope of the tangent to the curve is $1\frac{1}{2}$ times its slope at the origin.

[4] The ultimate strength values were taken as the unit load necessary to produce a deformation of 25 per cent of the length of the specimen.

[5] These values are the average Brinell number of three impressions on each alloy using a 10-mm. ball and a 500-kg. load applied for 30 seconds

STANDARD SPECIFICATIONS
FOR
COPPER PLATES FOR LOCOMOTIVE FIREBOXES[1]

Serial Designation: B 11 – 18

These specifications are issued under the fixed designation B 11; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1916; ADOPTED, 1918.

Scope.

1. These specifications cover two grades of copper for locomotive fireboxes, namely, Arsenical and Non-Arsenical.

MANUFACTURE

Process.

2. The copper shall be fire-refined or electrolytic, and hot rolled from suitable cakes.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

3. The copper shall conform to the following requirements as to chemical composition:

(*a*) *Arsenical Copper.*—Arsenical copper shall contain 0.25 to 0.50 per cent of arsenic, and shall not contain more than 0.120 per cent of impurities, exclusive of arsenic and silver.

(*b*) *Non-Arsenical Copper.*—Non-Arsenical copper shall have a purity of at least 99.880 per cent, as determined by electrolytic assay, silver being counted as copper. The total of impurities other than silver shall not exceed 0.120 per cent.

Chemical Analyses.

4. An analysis may be made by the purchaser from a broken tension test specimen representing each plate as rolled. The chemical composition thus determined shall conform to the requirements specified in Section 3.

PHYSICAL PROPERTIES AND TESTS

Tension Tests.

5. The material shall conform to the following minimum requirements as to tensile properties:

	ARSENICAL.	NON-ARSENICAL.
Tensile strength, lb. per sq. in.	31 000	30 000
Elongation in 8 in., per cent	35	30

Bend Tests.

6. The specimen shall bend both hot (500 to 700° C.) and cold 180 deg. without cracking on the outside of the bent portion

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee B-2 on Non-Ferrous Metals and Alloys.

as follows: For material 1 in. or under in thickness, flat on itself; and for material over 1 in. in thickness, around a pin the diameter of which is equal to the thickness of the specimen.

Test Specimens.

7. Tension and bend test specimens shall be taken from the finished rolled material. They shall be of the full thickness of material as rolled, and shall be machined to the form and dimensions shown in Fig. 1; except that bend test specimens may be machined with both edges parallel.

Number of Tests.

8. (*a*) One tension, one cold-bend and one hot-bend test shall be made from each plate as rolled.

(*b*) If any test specimen develops flaws it may be discarded and two other specimens substituted, each of which shall be free from flaws. If flaws appear in either or both of the substituted specimens the lot shall be rejected.

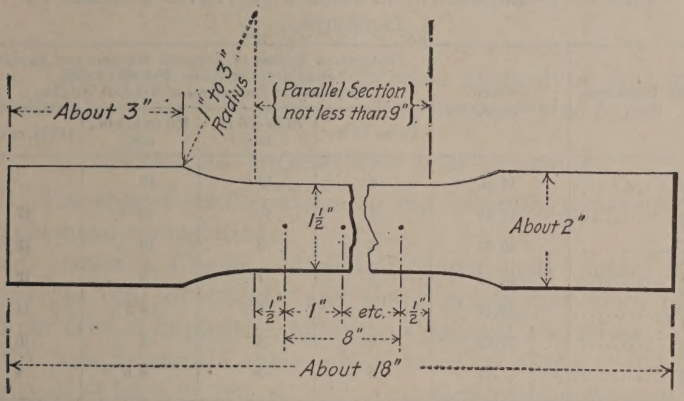


FIG. 1.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 5 and any part of the fracture is outside the middle third of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

(*d*) If any test specimen shows defective machining it may be discarded and another specimen substituted.

PERMISSIBLE VARIATIONS IN WEIGHT AND THICKNESS

Dimensional Variations.

9. The thickness of each plate shall not vary more than 0.04 in. under that ordered. An excess over the nominal weight corresponding to the dimensions on the order shall be allowed for each plate if not more than that shown in Table I. One cubic inch of rolled copper is assumed to weigh 0.323 lb.

FINISH

Finish. 10. The finished plates shall be free from injurious defects and shall have a workmanlike finish.

MARKING

Marking. 11. The name or brand of the manufacturer, plate number, and grade shall be stamped on each plate. The plate number shall be legibly stamped on each test specimen.

INSPECTION AND REJECTION

Inspection. 12. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the plates are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at

TABLE I.—PERMISSIBLE OVERWEIGHTS OF PLATES ORDERED TO THICKNESS.

ORDERED THICKNESS, IN.	WEIGHT, LB. PER SQ. FT.	PERMISSIBLE EXCESS IN AVERAGE WEIGHTS PER SQUARE FOOT OF PLATES FOR WIDTHS GIVEN. Expressed in Percentages of Nominal Weights.			
		Under 75 in.	75 to 100 in., excl.	100 to 115 in., excl.	115 in. or over.
$\frac{5}{16}$	14.53	8	12	16	..
$\frac{3}{8}$	17.44	7	10	13	17
$\frac{7}{16}$	20.34	6	8	10	13
$\frac{1}{2}$	23.25	5	7	9	12
$\frac{9}{16}$	26.16	5	6.5	8.5	11
$\frac{5}{8}$	29.06	5	6	8	10
Over $\frac{5}{8}$	.....	5	5	6.5	9

the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection. 13. (*a*) Unless otherwise specified, any rejection based on chemical and physical tests made in accordance with these specifications shall be reported within five working days from the receipt of samples.

(*b*) Plates which, subsequent to their acceptance at the manufacturer's works, are shown to have contained injurious defects will be rejected, and the manufacturer shall be notified.

Rehearing. 14. Samples tested in accordance with Section 4, which represent rejected plates, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

STANDARD SPECIFICATIONS
FOR
COPPER BARS FOR LOCOMOTIVE STAYBOLTS[1]

Serial Designation: B 12 – 21

These specifications are issued under the fixed designation B 12; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1916; ADOPTED, 1918; REVISED, 1921.

Scope.

1. These specifications cover two grades of copper for locomotive staybolts, namely, Arsenical and Non-Arsenical.

MANUFACTURE

Process.

2. The copper shall be fire-refined or electrolytic and shall be finished to dimensions by hot rolling from suitable bars.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

3. The copper shall conform to the following requirements as to chemical composition:

(*a*) *Arsenical Copper.*—Arsenical copper shall contain 0.25 to 0.50 per cent of arsenic, and shall contain not more than 0.120 per cent of impurities, exclusive of arsenic and silver.

(*b*) *Non-Arsenical Copper.*—Non-Arsenical copper shall have a purity of at least 99.880 per cent, as determined by electrolytic assay, silver being counted as copper. The total of impurities other than silver shall not exceed 0.120 per cent.

Chemical Analyses.

4. An analysis may be made from one sample for each 5000 lb. or fraction thereof of finished bars. The chemical composition thus determined shall conform to the requirements specified in Section 3.

PHYSICAL PROPERTIES AND TESTS

Tension Tests.

5. The material shall conform to the following minimum requirements as to tensile properties:

	ARSENICAL.	NON-ARSENICAL.
Tensile strength, lb. per sq. in.....	31 000	30 000
Elongation in 8 in., per cent.....	35	30

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee B-2 on Non-Ferrous Metals and Alloys.

Bend Tests. 6. The test specimen shall bend cold through 180 deg. flat on itself without cracking on the outside of the bent portion.

Test Specimens. 7. Tension and bend test specimens shall be of the full-size section of the bars as rolled.

Number of Tests. 8. (*a*) One tension and one bend test shall be made from each 5000 lb. or fraction thereof.

(*b*) If any test specimen develops flaws it may be discarded and two other specimens substituted, each of which shall be free from flaws. If flaws appear in either or both of the substituted specimens the lot shall be rejected.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 5 and any part of the fracture is outside the middle third of gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

(*d*) If any test specimen shows defective machining it may be discarded and another specimen substituted.

PERMISSIBLE VARIATIONS IN DIAMETER

Dimensional Variations. 9. The bars shall be truly round within 0.01 in., and shall not vary more than 0.01 in. over nor more than 0.005 in. under the specified size.

WORKMANSHIP AND FINISH

Finish. 10. The finished bars shall be free from injurious defects and shall have a workmanlike finish.

MARKING

Marking. 11. The finished bars shall, when loaded for shipment, be properly separated and marked with the name or brand of the manufacturer and the lot number for identification. The lot number shall be legibly marked on each test specimen.

INSPECTION AND REJECTION

Inspection. 12. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the bars are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection. 13. (*a*) Unless otherwise specified, any rejection based on chemical or physical tests made in accordance with these

specifications shall be reported within five working days from the receipt of samples.

(*b*) Bars which, subsequent to their acceptance at the manufacturer's works, are shown to have contained injurious defects will be rejected, and the manufacturer shall be notified.

Rehearing.

14. Samples tested in accordance with Section 4, which represent rejected bars, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

STANDARD SPECIFICATIONS
FOR
SEAMLESS COPPER BOILER TUBES[1]

Serial Designation: B 13 – 18

These specifications are issued under the fixed designation B 13; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1916; ADOPTED, 1918.

Scope.

1. These specifications cover two grades of copper tubes for locomotive boilers, namely, Arsenical and Non-Arsenical.

MANUFACTURE

Process.

2. The copper shall be fire-refined or electrolytic and shall be made into tubes either by the hot-rolling or cold-drawing process. It shall be finished by cold drawing.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

3. The copper shall conform to the following requirements as to chemical composition:

(*a*) *Arsenical Copper.*—Arsenical copper shall contain from 0.15 to 0.35 per cent of arsenic, and shall not contain more than 0.120 per cent of impurities, exclusive of arsenic and silver.

(*b*) *Non-Arsenical Copper.*—Non-Arsenical copper shall have a purity of at least 99.880 per cent, as determined by electrolytic assay, silver being counted as copper. The total of impurities other than silver shall not exceed 0.120 per cent.

Chemical Analyses.

4. (*a*) Analyses of two tubes in each lot of 250 or less may be made by the purchaser. The chemical composition thus determined shall conform to the requirements specified in Section 3. Drillings for analyses shall be taken from several points around each tube, or turnings may be taken from the end of the tube.

(*b*) If the analysis of any one tube does not conform to the requirements specified, analyses of two additional tubes from the same lot shall be made, each of which shall conform to the requirements specified.

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee B-2 on Non-Ferrous Metals and Alloys.

PHYSICAL PROPERTIES AND TESTS

Temper. 5. Tubes will be furnished hard or annealed, as specified. Test specimens taken from hard tubes shall be annealed before testing.

Flange Tests. 6. (*a*) A test specimen not more than 4 in. in length shall have a flange turned over at right angles to the body of the tube, without showing cracks or flaws. This flange, as measured from the outside of the tube, shall be $\frac{3}{8}$ in. wide for tubes $2\frac{1}{2}$ in. or under in outside diameter, and $\frac{1}{2}$ in. wide for tubes over $2\frac{1}{2}$ in. in outside diameter.

(*b*) In making the flange test, it is recommended that the flaring tool and die block shown in Fig. 1 be used.

Crush Tests. 7. A test specimen $2\frac{1}{2}$ in. in length shall withstand crushing longitudinally until the outside folds are in contact, without showing cracks or flaws.

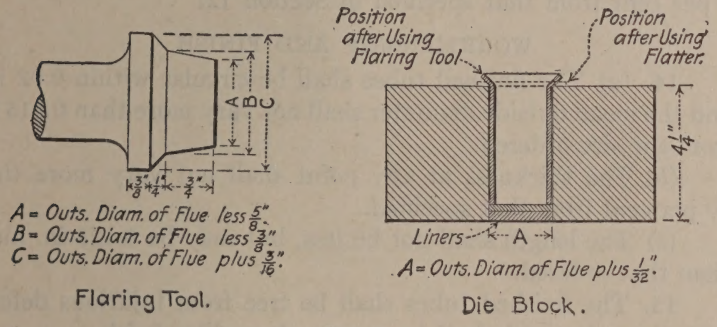


FIG. 1.

Hydrostatic Tests. 8. All tubes shall withstand an internal hydrostatic pressure of 750 lb. per sq. in. The hydrostatic pressure test shall be applied to the finished tubes before annealing.

Test Specimens. 9. (*a*) Test specimens shall consist of sections cut from tubes selected by the inspector representing the purchaser from the lot offered for shipment. They shall be smooth on the ends and free from burrs.

(*b*) All specimens shall be tested cold.

Number of Tests. 10. One flange and one crush test shall be made from each of two tubes in each lot of 250 or less. Each tube shall be subjected to the hydrostatic test.

Retests. 11. If the results of the physical tests of only one tube from any lot do not conform to the requirements specified, retests of two additional tubes from the same lot shall be made, each of which shall conform to the requirements specified.

STANDARD WEIGHTS

Standard Weights.

12. The standards weights for tubes of various outside diameters and thicknesses are as follows:

Thickness.		Weight, lb. per ft. of Length. Outside Diameter, in.				
B. w. g.	In.	$1\frac{1}{2}$	$1\frac{3}{4}$	2	$2\frac{1}{4}$	$2\frac{1}{2}$
13	0.095	1.624	1.913	2.202	2.491	2.779
12	0.109	1.844	2.176	2.507	2.839	3.170
11	0.120	2.015	2.380	2.744	3.109	3.474
10	0.134	2.227	2.634	3.042	3.449	3.857
9	0.148	2.434	2.884	3.334	3.785	4.235

Permissible Variations.

13. The weight of the tubes shall not vary more than 5 per cent from that specified in Section 12.

WORKMANSHIP AND FINISH

Workmanship.

14. (*a*) The finished tubes shall be circular within 0.02 in., and the mean outside diameter shall not vary more than 0.015 in. from the size ordered.

(*b*) The thickness at any point shall not vary more than 10 per cent from that specified.

(*c*) The length shall not be less, but may be 0.125 in. more than that ordered.

Finish.

15. The finished tubes shall be free from injurious defects and distortion and shall have a workmanlike finish.

MARKING

Marking.

16. The name or brand of the manufacturer, and "tested at 750 lb." shall be legibly stenciled on each tube.

INSPECTION AND REJECTION

Inspection.

17. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the tubes are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection.

18. (*a*) Unless otherwise specified, any rejection based on chemical or physical tests made in accordance with these specifications shall be reported within five working days from the receipt of samples.

(*b*) Tubes when inserted in the boiler shall withstand expanding and bending without showing cracks or flaws. Tubes which fail in this manner will be rejected, and the manufacturer shall be notified.

19. Samples tested in accordance with Section 4, which represent rejected tubes, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time. Rehearing.

STANDARD SPECIFICATIONS
FOR
SEAMLESS BRASS BOILER TUBES[1]

Serial Designation: B 14 – 18

These specifications are issued under the fixed designation B 14; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1916; ADOPTED, 1918.

Scope.

1. These specifications cover brass tubes for locomotive boilers.

MANUFACTURE

Process.

2. The tubes shall be cold drawn to size and semi-annealed. They shall be fully annealed at both ends, if so ordered.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

3. The material shall conform to the following requirements as to chemical composition:

70–30 ALLOY.

Copper	not under	69.00	per cent
Lead	not over	0.50	"
Iron	" "	0.10	"
Materials other than copper and zinc.	" "	0.50	"
Zinc	remainder		

Chemical Analyses.

4. (*a*) Analyses of two tubes in each lot of 250 or less may be made by the purchaser. The chemical composition thus determined shall conform to the requirements specified in Section 3. Drillings or turnings for analyses may be taken from the end of the tube.

(*b*) If the analysis of any one tube does not conform to the requirements specified, analyses of two additional tubes from the same lot shall be made, each of which shall conform to the requirements specified.

PHYSICAL PROPERTIES AND TESTS

Temper.

5. Test specimens taken from semi-annealed tubes shall be fully annealed before testing.

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee B-2 on Non-Ferrous Metals and Alloys.

6. (*a*) A test specimen not more than 4 in. in length shall have a flange turned over at right angles to the body of the tube without showing cracks or flaws. The outside diameter of this flange shall measure not less than $1\frac{1}{4}$ times the original outside diameter of the tube. **Flange Test**

(*b*) In making the flange test, it is recommended that the flaring tool and die block shown in Fig. 1 be used.

7. The tubes shall be capable of standing the following test, when cold, without showing cracks or flaws: A piece of the tube shall be flattened down, until the interior surfaces of the tube meet, and then be doubled over on itself, that is, bent through an angle of 180 deg., the bend being at right angles to the direction of the length of the tube. **Flattening and Doubling-Over Test.**

8. All tubes shall withstand an internal hydrostatic pressure of 750 lb. per sq. in. **Hydrostatic Test.**

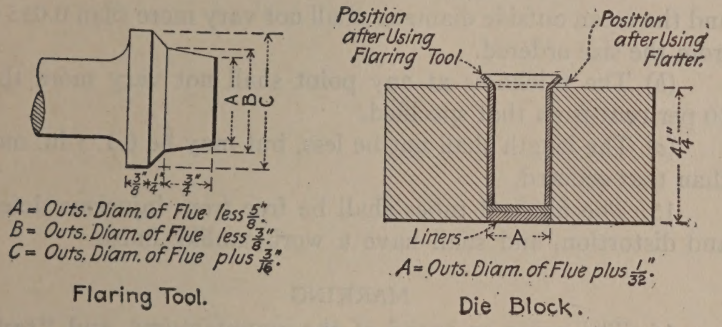


FIG. 1.

9. (*a*) Test specimens shall consist of sections cut from tubes selected by the inspector representing the purchaser from the lot offered for shipment. They shall be smooth on the ends and free from burrs. **Test Specimens.**

(*b*) All specimens shall be tested cold.

10. One flange and one flattening test shall be made from each of two tubes in each lot of 250 or less. Each tube shall be subjected to the hydrostatic test. **Number of Tests.**

11. If the results of the physical tests of only one tube from any lot do not conform to the requirements specified, retests of two additional tubes from the same lot shall be made, each of which shall conform to the requirements specified. **Retests.**

STANDARD WEIGHTS

12. The standard weights for tubes of various outside diameters and thicknesses are as follows: **Standard Weights.**

Thickness.		Weight lb. per ft. of Length. Outside Diameter, in.				
B. w. g.	In.	$1\frac{1}{2}$	$1\frac{3}{4}$	2	$2\frac{1}{4}$	$2\frac{1}{2}$
13	0.095	1.551	1.827	2.102	2.378	2.654
12	0.109	1.761	2.078	2.395	2.711	3.028
11	0.120	1.924	2.272	2.621	2.969	3.318
10	0.134	2.127	2.516	2.905	3.294	3.683
7	0.148	2.325	2.755	3.184	3.614	4.044

Permissible Variations.

13. The weight of the tubes shall not vary more than 5 per cent from that specified in Section 12.

WORKMANSHIP AND FINISH

Workmanship.

14. (*a*) The finished tubes shall be circular within 0.02 in., and the mean outside diameter shall not vary more than 0.015 in. from the size ordered.

(*b*) The thickness at any point shall not vary more than 10 per cent from that specified.

(*c*) The length shall not be less, but may be 0.125 in. more than that ordered.

Finish.

15. The finished tubes shall be free from injurious defects and distortion, and shall have a workmanlike finish.

MARKING

Marking.

16. The name or brand of the manufacturer, and "tested at 750 lb." shall be legibly stenciled on each tube.

INSPECTION AND REJECTION

Inspection.

17. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the tubes are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection.

18. (*a*) Unless otherwise specified, any rejection based on chemical and physical tests made in accordance with these specifications shall be reported within five working days from the receipt of samples.

(*b*) Tubes when inserted in the boiler shall withstand expanding and bending without showing cracks or flaws. Tubes

which fail in this manner will be rejected, and the manufacturer shall be notified.

19. Samples tested in accordance with Section 4, which represent rejected tubes, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time. Rehearing.

STANDARD SPECIFICATIONS
FOR
SEAMLESS ADMIRALTY CONDENSER TUBES AND FERRULE STOCK[1]

Serial Designation: B 44 – 24

These specifications are issued under the fixed designation B 44; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1922; ADOPTED IN AMENDED FORM, 1924.

Scope.

1. These specifications cover seamless tubes and ferrule stock made from Admiralty alloy for condenser use.

MANUFACTURE

Process.

2. The tubes shall be cold drawn to size from an alloy made from lake or electrolytic copper, conforming to the requirements of either the Standard Specifications for Lake Copper Wire Bars, Cakes, Slabs, Billets, Ingots and Ingot Bars (Serial Designation: B 4)[2] or the Standard Specifications for Electrolytic Copper Wire Bars, Cakes, Slabs, Billets, Ingots and Ingot Bars (Serial Designation: B 5)[3] of the American Society for Testing Materials, and zinc of Grade No. 1 of the Standard Specifications for Spelter (Serial Designation: B 6) of the American Society for Testing Materials,[4] and Straits tin or its equivalent. Scrap shall not be used except such as may result from the manufacture of articles of the same composition.

Annealing.

3. (*a*) Condenser tubes shall be annealed sufficiently to enable the tubes to pass the physical and metallographic tests herein specified.

(*b*) Tubes for ferrule stock shall be sufficiently annealed to prevent cracking, but they need not be held within the close limits specified for condenser tubes.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

4. The material shall conform to the following requirements as to chemical composition (Note 1):

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee B-2 on Non-Ferrous Metals and Alloys.

[2] See p. 515. [3] See p. 520. [4] See p. 524.

Copper	not less than 70.00 per cent
Tin	0.90 to 1.20 "
Lead	not over 0.075 "
Iron	not over 0.06 "
Zinc	remainder

Sampling.

5. The sample for chemical analysis shall consist of drillings, millings, or clippings taken from at least three separate tubes from each lot of 600 tubes or less, equal quantities being taken from each tube and thoroughly mixed. Samples so prepared shall be divided into three equal parts, each of which shall be placed in a sealed package, one for the seller, one for the purchaser, and one for an umpire, if necessary.

PHYSICAL PROPERTIES AND TESTS

Microscopic Examination.

6. (*a*) A microscopic examination of the tubes shall show sufficient annealing for complete recrystallization with a uniform grain size not in excess of 0.045 mm. in average diameter, the grain size approaching as closely as possible a mean diameter of not over 0.035 mm. (Note 2).

(*b*) The determination of grain size shall be made by comparison of micrographs representing the samples with micrographs of standard specimens for which the grain size has been accurately determined. The magnification in all such micrographs shall be 75 diameters. The standard micrographs shall be taken from specimens, the grain size of which has been determined by Jeffries' method for grain size measurements as described in the Standard Rules Governing the Preparation of Micrographs of Metals and Alloys (Serial Designation: E 2) of the American Society for Testing Materials[1] at a magnification of 250 diameters. Reproductions of micrographs so prepared are appended hereto.

Hammering Test.

7. The tubes shall be capable of withstanding the following test without showing cracks or flaws: Pieces cut from the ends of the tubes shall be hammered flat on different elements throughout their length so that a gage set at 3 times the thickness of the metal shall pass over the tube freely throughout the flattened part, except at such points where changes in the elements of flattening take place.

Expanding Test.

8. The tubes shall be capable of withstanding the following test without showing signs of cracking or rupture: A pin having a taper of $1\frac{1}{2}$ in. per foot shall be driven into the tube until the diameter has been increased 20 per cent.

Strain Test.

9. A test specimen 6 in. in length shall withstand an immersion in an aqueous mercurous nitrate solution containing 100 g. of mercurous nitrate and 13 cc. of nitric acid (sp. gr. 1.42) per liter of solution for 15 minutes, without cracking (Note 3).

[1] See p. 778.

Hydrostatic Test. 10. All tubes shall withstand an internal hydrostatic pressure of 1000 lb. per sq. in. without leakage and shall show no sign of strain or cracking (Note 4).

Number of Tests. 11. Tubes shall be grouped into lots of 600 tubes or less. Two tubes shall be selected from each lot and subjected to the physical tests specified in Sections 6 to 9, inclusive.

PERMISSIBLE VARIATIONS IN DIMENSIONS

Thickness. 12. No tube at its thinnest point shall be less than the thickness specified.

Length. 13. The length shall not be less but may be $\frac{1}{16}$ in. more than that ordered when measured at a temperature of 68° F. (20° C.).

Weights 14. No single tube that exceeds the calculated weight by more than 5 per cent will be accepted. One cubic inch of the material is assumed to weigh 0.308 lb.

WORKMANSHIP AND FINISH

Workmanship. 15. The tubes shall be round, straight and of uniform thickness throughout. They shall be free from cracks, seams, slivers, scale and other surface defects both inside and outside.

Finish. 16. All tubes shall be acid cleaned after the final annealing.

INSPECTION AND REJECTION

Rejection. 17. If any test specimen representing a lot fails to meet the requirements of Section 4 and Sections 6 to 8, inclusive, two additional specimens, at the option of the manufacturer, may be taken as before and submitted for check analysis or subjected to any tests in which the original specimen failed, but each of these specimens shall conform to the requirements specified.

Inspection. 18. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the tubes are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

EXPLANATORY NOTES

NOTE 1.—The ideal composition for Admiralty metal is 70 per cent of copper, 29 per cent of zinc, and 1 per cent of tin, and better tubes will be obtained by adhering as closely as possible to this composition, particularly as to tin. It does not, therefore, seem wise to make 1 per cent of tin the minimum but rather in order to obtain as nearly 1 per cent as possible to allow some variation under 1 per cent and make the minimum limit for tin 0.90 per cent. Owing to the fact that a minimum of 1 per cent tin has heretofore existed, cases will occur, until the present specifications become universal, where the tin may

exceed the 1.20-per-cent maximum. It is not considered that this would be harmful or should be made a cause for rejection.

NOTE 2.—The so-called "Compression Test" requiring that tubes of varying sizes and thicknesses should be subjected to certain arbitrary pressures without more than 0.005 in. permanent deformation has not been included because the physical properties of the tube under compression are functions of the temperature at which it receives its final heat treatment and the metallographic examination sufficiently indicates the temper of the tube to decide whether it may be properly packed in the condenser head.

Until concrete information is available relative to the effect of grain size on corrosion, the committee points out that Section 6 (*a*) has been prepared solely for the purpose of getting a measurement of the compressibility and freedom from stress.

(*a*) Mean Crystal Diameter 0.035 mm. (× 75).

(*b*) Mean Crystal Diameter 0.045 mm. (× 75).

FIG. 1.—Microstructure of Admiralty Metal, Etched with NH_4OH-H_2O_2

NOTE 3.—Since the specifications require that the tubes shall be annealed sufficiently to establish crystallin equilibrium and show a grain size within certain definite limits, it would seem that a test for internal strains might be unnecessary. The mercurous nitrate test has been included, however, to guard against the hardening of tubes by light drawing operations which would not deform the crystals to an extent recognizable by microscopic examination.

NOTE 4.—Provision is made for the testing of each tube separately to 1000 lb. per sq. in. hydrostatic pressure in order to develop and make evident fractures or punctures which may have occurred in the process of manufacture. This is a 100 per cent test and it is not necessary to again test all the tubes by subjecting them to 80 lb. per sq. in. pneumatic pressure while immersed in water. Both of these tests are made to detect the same kind of faults and either if carried out according to the intent of the specifications should be sufficient. The 1000-lb. hydrostatic pressure test is the more searching and has been specified. The multiplication of tests to determine the same facts under the plea that there may be carelessness in applying one or another should not be encouraged.

STANDARD SPECIFICATIONS
FOR
SEAMLESS 70–30 BRASS CONDENSER TUBES AND FERRULE STOCK[1]

Serial Designation: B 55 – 25

These specifications are issued under the fixed designation B 55; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1924; ADOPTED, 1925.

Scope.

1. These specifications cover seamless tubes and ferrule stock made from 70-30 brass for condenser use.

MANUFACTURE

Process.

2. The tubes shall be cold drawn to size from an alloy made from lake or electrolytic copper, conforming to the requirements of either the Standard Specifications for Lake Copper Wire Bars, Cakes, Slabs, Billets, Ingots and Ingot Bars (Serial Designation: B 4)[2] or the Standard Specifications for Electrolytic Copper Wire Bars, Cakes, Slabs, Billets, Ingots and Ingot Bars (Serial Designation: B 5)[3] of the American Society for Testing Materials,[1] and zinc of Grade No. 1 of the Standard Specifications for Spelter (Serial Designation: B 6) of the American Society for Testing Materials.[4] Scrap shall not be used except such as may result from the manufacture of articles of the same composition.

Annealing.

3. (*a*) Condenser tubes shall be annealed sufficiently to enable the tubes to pass the physical and metallographic tests herein specified.

(*b*) Tubes for ferrule stock shall be sufficiently annealed to prevent cracking, but they need not be held within the close limits specified for condenser tubes.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

4. The material shall conform to the following requirements as to chemical composition:

Copper	not less than 70.00 per cent
Lead	not over 0.075 "
Iron	not over 0.06 "
Zinc	remainder

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee B-2 on Non-Ferrous Metals and Alloys.

[2] See p. 515. [3] See p. 520. [4] See p. 524.

Sampling.

5. The sample for chemical analysis shall consist of drillings, millings, or clippings taken from at least three separate tubes from each lot of 600 tubes or less, equal quantities being taken from each tube and thoroughly mixed. Samples so prepared shall be divided into three equal parts, each of which shall be placed in a sealed package, one for the seller, one for the purchaser, and one for an umpire, if necessary.

PHYSICAL PROPERTIES AND TESTS

Microscopic Examination.

6. (*a*) A microscopic examination of the tubes shall show sufficient annealing for complete recrystallization with a uniform grain size not in excess of 0.045 mm. in average diameter, the grain size approaching as closely as possible a mean diameter of not over 0.035 mm. (Note 1).

(*b*) The determination of grain size shall be made by comparison of micrographs representing the samples with micrographs of standard specimens for which the grain size has been accurately determined. The magnification in all such micrographs shall be 75 diameters. The standard micrographs shall be taken from specimens the grain size of which has been determined by Jeffries' method for grain size measurements as described in the Standard Rules Governing the Preparation of Micrographs of Metals and Alloys (Serial Designation: E 2) of the American Society for Testing Materials[1] at a magnification of 250 diameters. Reproductions of micrographs so prepared are appended hereto.

Hammering Test.

7. The tubes shall be capable of withstanding the following test without showing cracks or flaws: Pieces cut from the ends of the tubes shall be hammered flat on different elements throughout their length so that a gage set at 3 times the thickness of the metal shall pass over the tube freely throughout the flattened part, except at such points where changes in the elements of flattening take place.

Expanding Test.

8. The tubes shall be capable of withstanding the following test without showing signs of cracking or rupture: A pin having a taper of $1\frac{1}{2}$ in. per foot shall be driven into the tube until the diameter has been increased 20 per cent.

Strain Test.

9. A test specimen 6 in. in length shall withstand an immersion in an aqueous mercurous nitrate solution containing 100 g. of mercurous nitrate and 13 cc. of nitric acid (sp. gr. 1.42) per liter of solution for 15 minutes, without cracking (Note 2).

Hydrostatic Test.

10. All tubes shall withstand an internal hydrostatic pressure of 1000 lb. per sq. in. without leakage and shall show no sign of strain or cracking (Note 3).

[1] See p. 778.

Number of Tests. 11. Tubes shall be grouped into lots of 600 tubes or less. Two tubes shall be selected from each lot and subjected to the physical tests specified in Sections 6 to 9, inclusive.

PERMISSIBLE VARIATIONS IN DIMENSIONS

Diameter. 12. The outside diameter of the tubes shall not vary from that specified by more than the following amounts, as measured by "go" and "no go" ring gages:

NOMINAL DIAMETER, IN.	PERMISSIBLE VARIATION, IN.
Up to 0.500, inclusive	±0.002
Over 0.500 to 0.740, inclusive	±0.0025
Over 0.740 to 1.000, inclusive	±0.003
Over 1.000 to 1.250, inclusive	±0.0035
Over 1.250 to 1.500, inclusive	±0.004

Thickness. 13. No tube at its thinnest point shall be less than the thickness specified.

Length. 14. The length shall not be less but may be $\frac{1}{16}$ in. more than that ordered when measured at a temperature of 20° C. (68° F.).

Weight. 15. No single tube that exceeds the calculated weight by more than 5 per cent will be accepted. One cubic inch of the material is assumed to weigh 0.308 lb.

WORKMANSHIP AND FINISH

Workmanship. 16. The tubes shall be round, straight and of uniform thickness throughout. They shall be free from cracks, seams, slivers, scale and other surface defects both inside and outside.

Finish. 17. All tubes shall be acid cleaned after the final annealing.

INSPECTION AND REJECTION

Retest. 18. If any test specimen representing a lot fails to meet the requirements of Section 4 and Sections 6 to 8, inclusive, two additional specimens, at the option of the manufacturer, may be taken as before and submitted for check analysis or subjected to any tests in which the original specimen failed, but each of these specimens shall conform to the requirements specified.

Inspection. 19. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the tubes are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

EXPLANATORY NOTES

NOTE 1.—The so-called "Compression Test" requiring that tubes of varying sizes and thicknesses should be subjected to certain arbitrary pressures without more than 0.005 in. permanent deformation has not been included because the physical properties of the tube under compression are functions of the temperature at which it receives its final heat treatment and the metallographic examination sufficiently indicates the temper of the tube to decide whether it may be properly packed in the condenser head.

Until concrete information is available relative to the effect of grain size on corrosion, the committee points out that Section 6 (*a*) has been prepared solely for the purpose of getting a measurement of the compressibility and freedom from stress.

NOTE 2.—Since the specifications require that the tubes shall be annealed sufficiently to establish crystallin equilibrium and show a grain size within

(*a*) Mean Crystal Diameter 0.035 mm. (× 75).

(*b*) Mean Crystal Diameter 0.045 mm. (× 75).

FIG. 1.—Microstructure of 70-30 Brass, Etched with NH_4OH-H_2O_2.

certain definite limits, it would seem that a test for internal strains might be unnecessary. The mercurous nitrate test has been included, however, to guard against the hardening of tubes by light drawing operations which would not deform the crystals to an extent recognizable by microscopic examination.

NOTE 3.—Provision is made for the testing of each tube separately to 1000 lb. per sq. in. hydrostatic pressure in order to develop and make evident fractures or punctures which may have occurred in the process of manufacture. This is a 100 per cent test and it is not necessary to again test all the tubes by subjecting them to 80 lb. per sq. in. pneumatic pressure while immersed in water. Both of these tests are made to detect the same kind of faults and either, if carried out according to the intent of the specifications, should be sufficient. The 1000-lb. hydrostatic pressure test is the more searching and has been specified. The multiplication of tests to determine the same facts under the plea that there may be carelessness in applying one or another should not be encouraged.

STANDARD SPECIFICATIONS
FOR
SEAMLESS MUNTZ METAL CONDENSER TUBES AND FERRULE STOCK[1]

Serial Designation: B 56 - 25

These specifications are issued under the fixed designation B 56; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1924; ADOPTED, 1925.

Scope.

1. These specifications cover seamless tubes and ferrule stock made from Muntz metal for condenser use.

MANUFACTURE

Process.

2. The tubes shall be made by any approved process, and finished by cold drawing, from an alloy made from lake or electrolytic copper, conforming to the requirements of either the Standard Specifications for Lake Copper Wire Bars, Cakes, Slabs, Billets, Ingots and Ingot Bars (Serial Designation: B 4)[2] or the Standard Specifications for Electrolytic Copper Wire Bars, Cakes, Slabs, Billets, Ingots and Ingot Bars (Serial Designation: B 5)[3] of the American Society for Testing Materials and Zinc of Grades Nos. 1, 2, or 3 of the Standard Specifications for Spelter (Serial Designation: B 6) of the American Society for Testing Materials.[4] Scrap of equivalent grades may be used.

Annealing.

3. The tubes and ferrule stock shall be annealed sufficiently to enable the tubes to pass the metallographic and physical tests herein specified, and shall be suitable for packing in tube plates.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

4. The material shall conform to the following requirements as to chemical composition:

Copper	59.00 to 63.00 per cent
Lead	not over 0.30 "
Iron	not over 0.07 "
Zinc	remainder

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee B-2 on Non-Ferrous Metals and Alloys.

[2] See p. 515. [3] See p. 520. [4] See p. 524.

Sampling. 5. The sample of chemical analysis shall consist of drillings, millings, or clippings taken from at least three separate tubes from each lot of 600 tubes or less, equal quantities being taken from each tube and thoroughly mixed. Samples so prepared shall be divided into three equal parts, each of which shall be placed in a sealed package, one for the seller, one for the purchaser, and one for an umpire, if necessary.

PHYSICAL PROPERTIES AND TESTS

Microscopic Examination. 6. The tubes shall have been so annealed that, when magnified to 75 diameters, a properly prepared specimen shall show uniform and complete recrystallization.

Hammering Test. 7. The tubes shall be capable of withstanding the following test without showing cracks or flaws: Pieces cut from the remainder of the test tubes shall be hammered flat on different elements throughout their length so that a gage set at 3 times the thickness of the metal shall pass over the tube freely throughout the flattened part, except at such points where changes in the elements of flattening take place.

Expanding Test. 8. The tubes shall be capable of withstanding the following test without showing signs of cracking or rupture: A pin having a taper of $1\frac{1}{2}$ in. per foot shall be driven into the tube until the diameter has been increased 15 per cent.

Strain Test. 9. A test specimen 6 in. in length shall withstand an immersion in an aqueous mercurous nitrate solution containing 100 g. of mercurous nitrate and 13 cc. of nitric acid (sp. gr. 1.42) per liter of solution for 15 minutes, without cracking.

Hydrostatic Test. 10. All tubes shall withstand an internal hydrostatic pressure of 1000 lb. per sq. in. without leakage and shall show no sign of strain or cracking.

Number of Tests. 11. Tubes shall be grouped into lots of 600 tubes or less. Two tubes shall be selected from each lot and subjected to the physical tests specified in Sections 6 to 9, inclusive.

PERMISSIBLE VARIATIONS IN DIMENSIONS

Diameter. 12. The outside diameter of the tubes shall not vary from that specified by more than the following amounts, as measured by "go" and "no go" ring gages:

NOMINAL DIAMETER, IN.	PERMISSIBLE VARIATION, IN.
Up to 0.500, inclusive	±0.002
Over 0.500 to 0.740, inclusive	±0.0025
Over 0.740 to 1.000, inclusive	±0.003
Over 1.000 to 1.250, inclusive	±0.0035
Over 1.250 to 1.500, inclusive	±0.004

Thickness. 13. No tube at its thinnest point shall be less than the thickness specified.

Length. 14. The length shall not be less but may be $\frac{1}{16}$ in. more than that ordered when measured at a temperature of 20° C. (68° F.).

Weight. 15. No single tube that exceeds the calculated weight by more than 5 per cent will be accepted. One cubic inch of the material is assumed to weigh 0.306 lb.

WORKMANSHIP AND FINISH

Workmanship. 16. All tubes shall be round, straight and free from cracks, seams, slivers, scale and other defects, both inside and outside.

Finish. 17. All tubes shall be acid cleaned after the final annealing.

INSPECTION AND REJECTION

Retest. 18. If any test specimen representing a lot fails to meet the requirements of Section 4 and Sections 6 to 8, inclusive, two additional specimens, at the option of the manufacturer, may be taken as before and submitted for check analysis or subjected to any tests in which the original specimen failed, but each of these specimens shall conform to the requirements specified.

Inspection. 19. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the tubes are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

STANDARD SPECIFICATIONS
FOR
MUNTZ METAL CONDENSER TUBE PLATES[1]

Serial Designation: B 57 – 27

These specifications are issued under the fixed designation B 57; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1925; ADOPTED, 1927.

Scope.

1. These specifications cover rolled Muntz metal plates for surface condenser tube sheets.

MANUFACTURE

Process.

2. The plates shall be made by hot rolling from castings of suitable dimensions.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

3. The plates shall conform to the following requirements as to chemical composition:

Copper	58.00 – 61.00 per cent
Lead	0.35 – 0.90 "
Iron	not over 0.15 "
Tin	not over 0.25 "
Other Impurities	not over 0.10 "
Zinc	Remainder

Analysis.

4. Analysis may be made on each lot of 5000 lb. or less.

Sampling.

5. The sample shall be taken by drilling or milling representative plates in such a way that a sample of the entire thickness shall be obtained. Equal quantities from each plate shall be thoroughly mixed. Samples so prepared shall be divided into three equal parts, one for the seller, one for the purchaser, and one for an umpire, if necessary.

PHYSICAL PROPERTIES AND TESTS

Tension Tests.

6. The material shall conform to the following minimum requirements:

TENSILE STRENGTH, LB. PER SQ. IN.	YIELD POINT, LB. PER SQ. IN.	ELONGATION IN 2 IN., PER CENT
50 000	20 000	35.0

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee B-2 on Non-Ferrous Metals and Alloys.

Bend Test. 7. The bend test specimen shall stand being bent cold through 120 deg. around a pin, the diameter of which is equal to twice the thickness of the specimen, without cracking on the outside of the bent portion.

Tension Test Specimens. 8. Tension test specimens may be 1 in. in width and of the full thickness of the plate as rolled, or may be machined to conform to the dimensions shown in Fig. 1, in which case the ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial.

Bend Test Specimens. 9. Bend test specimens shall be 0.5 by 1 in. in section with corners rounded to a radius not over $\frac{1}{16}$ in. In the case of thin plates, the specimen may have the same thickness as the plate, with corners rounded to a radius equal to one-fourth of the thickness of the plate.

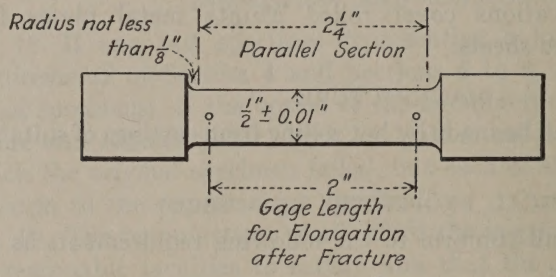

Radius not less than 1/8"
2 1/4"
Parallel Section
1/2" ± 0.01"
2"
Gage Length for Elongation after Fracture
Note:-The Gage Length, Parallel Section, and Fillets shall be as Shown, but the Ends may be of any Shape to fit the Holders of the Testing Machine in such a Way that the Load shall be axial.

FIG. 1

PERMISSIBLE VARIATIONS IN DIMENSIONS

Permissible Variations. 10. The thickness shall not vary from that specified by more than plus 3 per cent or minus 2 per cent.

WORKMANSHIP AND FINISH

Finish. 11. The plates shall be free from injurious defects and shall have a smooth clean surface. The fracture shall be uniform in color and grain throughout.

INSPECTION AND REJECTION

Inspection. 12. The manufacturer shall afford the inspector representing the purchaser, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications.

Rejection. 13. Material which fails to conform to these specifications will be rejected and the manufacturer shall be notified.

STANDARD SPECIFICATIONS
FOR
COPPER PIPE, STANDARD SIZES[1]

Serial Designation: B 42 – 24

These specifications are issued under the fixed designation B 42; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1922; ADOPTED, 1923; REVISED, 1924.

Scope.

1. These specifications cover seamless copper tubes and seamless copper pipe suitable for use in plumbing, boiler feed lines, etc.

MANUFACTURE

Process.

2. (*a*) The pipe shall be cold-drawn to size.

(*b*) When pipe is required for bending, the purchaser shall so specify, in which case the pipe shall be furnished with a proper bending temper.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

3. The copper shall have a purity of at least 99.880 per cent as determined by electrolytic assay, silver being counted as copper.

Sampling.

4. The sample for chemical analysis shall consist of drillings, millings, or clippings, taken from the test specimens specified in Section 9, equal quantities being taken from each specimen and thoroughly mixed. Samples so prepared shall be divided into three equal parts, each of which shall be placed in a sealed package, one for the seller, one for the purchaser, and one for an umpire if necessary.

PHYSICAL PROPERTIES AND TESTS

Tension Tests.

5. The material shall conform to the following minimum requirements as to tensile properties:

	Tensile Strength, lb. per sq. in.	Elongation in 4 in., per cent
Pipe less than 2 in. in outside diameter.....	40 000	10
Pipe 2 in. or over in outside diameter (after annealing)	30 000	25

Bend Tests.

6. (*a*) The test specimen, after being annealed, shall withstand being bent cold through 180 deg. without cracking on the outside of

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee B-2 on Non-Ferrous Metals and Alloys.

the bent portion as follows: For material less than ½ in. in thickness, flat on itself; and for material ½ in. or over in thickness, around a pin the diameter of whice is twice the thickness of the specimen.

(*b*) In the case of pipe for bending, annealed full sections of the pipe shall withstand being bent cold through 180 deg. without cracking on the outside of the bent portion, around a pin the diameter of which is 1½ times the inside diameter of the pipe. This test shall be in addition to the test specified in Paragraph (*a*).

Flange Test.

7. (*a*) An annealed test specimen, not more than 4 in. in length shall have a flange turned over at right angles to the body of the pipe without showing cracks or flaws. The width of this flange, as measured from the outside of the pipe, shall be one-fourth of the inside diameter of the pipe.

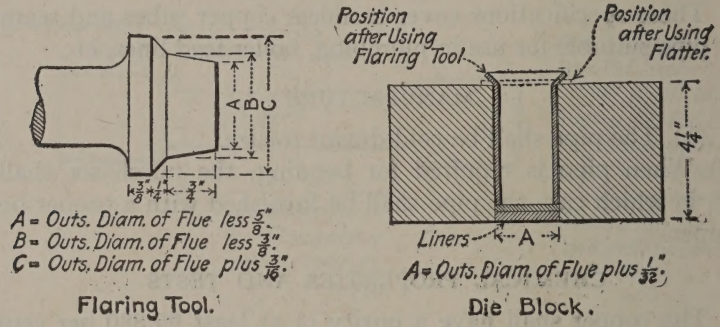


FIG. 1.

(*b*) In making the flange test, it is recommended that the flaring tool and die block shown in Fig. 1 be used.

Hydrostatic Test.

8. Each pipe shall withstand, without showing weakness or defects, an internal hydrostatic pressure sufficient to subject the material to a fiber stress of 6000 lb. per sq. in., determined by the formula for thin hollow cylinders under tension:

$$P = 2\frac{tS}{D}$$

in which P equals the pressure in pounds per square inch, t equals the thickness of wall in inches, D equals the outside diameter of the pipe in inches, and S equals the allowable unit stress of the material = 6000 lb. per sq. in. No pipe shall be tested beyond a pressure of 1000 lb. per sq. in. unless so specified.

Test Specimens.

9. (*a*) Tension test specimens for pipe less than 2 in. in outside diameter shall consist of a full section of the unannealed pipe; the ends shall be plugged with metal plugs which shall not extend within the gage marks.

(*b*) In the case of pipe 2 in. or over in outside diameter and not exceeding 6 in. in outside diameter, the test specimen shall be cut longitudinally. In the case of pipe exceeding 6 in. in outside diameter, the test specimen shall be cut circumferentially.

(*c*) The test specimen taken as specified in Paragraph (*b*), shall be heated to a cherry red and straightened while hot. It shall then be machined to conform in shape to Fig. 2. The width of the specimen shown in Fig. 2 shall be governed by the thickness of the material. For material $\frac{1}{4}$ in. or less in thickness, the width of the narrow portion

TABLE I.—STANDARD WEIGHTS AND DIMENSIONS FOR COPPER PIPE.

Size of Pipe, in.	Outside Diameter, in.	Standard Pipe		Extra Strong Pipe	
		Thickness, in.	Nominal Weight, lb. per foot of length	Thickness, in.	Nominal Weight, lb. per foot of length
$\frac{1}{8}$	0.405	0.0620	0.259	0.100	0.371
$\frac{1}{4}$	0.540	0.0825	0.460	0.123	0.624
$\frac{3}{8}$	0.675	0.0905	0.643	0.127	0.847
$\frac{1}{2}$	0.840	0.1075	0.957	0.149	1.25
$\frac{3}{4}$	1.050	0.1140	1.30	0.157	1.71
1	1.315	0.1265	1.83	0.182	2.51
$1\frac{1}{4}$	1.660	0.1460	2.69	0.194	3.46
$1\frac{1}{2}$	1.900	0.1500	3.20	0.203	4.19
2	2.375	0.1565	4.23	0.221	5.79
$2\frac{1}{2}$	2.875	0.1875	6.14	0.280	8.84
3	3.500	0.2190	8.75	0.304	11.82
$3\frac{1}{2}$	4.000	0.2500	11.41	0.321	14.37
4	4.500	0.2500	12.94	0.341	17.25
$4\frac{1}{2}$	5.000	0.2500	14.46	0.375	21.10
5	5.563	0.2505	16.21	0.375	23.67
6	6.625	0.2500	19.41	0.437	32.93
7	7.625	0.2815	25.17	0.500	43.34
8	8.625	0.3125	31.63	0.500	49.42
9	9.625	0.3440	38.83	0.500	55.56
10	10.750	0.3655	46.22	0.500	62.40

of the test specimen shall be approximately 1 in.; for material over $\frac{1}{4}$ in. in thickness, the width shall be such as to give a cross-section of approximately $\frac{1}{4}$ sq. in. in area, but in no case shall the width be less than the thickness of the material. The drawn surfaces shall not be machined, but be left in their original condition.

(*d*) The bend test specimen shall consist of a strip not over $1\frac{1}{2}$ in. in width, cut longitudinally from the pipe.

10. One bend test shall be made for each 2000 lb. or less of the finished product. For the remaining tests, a sufficient number of pipe shall be taken at random to constitute 0.5 per cent of the shipment. **Number of Tests.**

DIMENSIONS AND PERMISSIBLE VARIATIONS

Standard Weights. 11. The standard weights and dimensions for pipe of various outside diameters are given in Table I.

Permissible Variations. 12. (*a*) No single piece of pipe that exceeds the calculated weight by more than 5 per cent will be accepted. One cubic inch of the material is assumed to weigh 0.323 lb.

(*b*) The weight of the pipe shall vary not more than the following percentages from the weight specified in Section 11: Pipe 6 in. or less in diameter, 5 per cent; pipe from 6 to 8 in. in diameter, 7 per cent; pipe over 8 in. in diameter, 8 per cent.

WORKMANSHIP AND FINISH

Workmanship. 13. (*a*) The pipe shall be round and of uniform thickness throughout. They shall be free from cracks, seams, slivers, scale and other surface defects.

(*b*) The thickness at any point shall not be less than that specified in Section 11 by more than the following percentages: Pipe 6 in. of

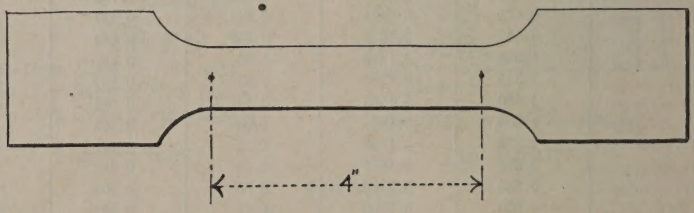


FIG. 2.

less in diameter, 5 per cent; pipe from 6 to 8 in. in diameter, 7 per cent; pipe over 8 in. in diameter, 8 per cent.

INSPECTION AND REJECTION

Rejection. 14. When the pipe is finished, and ready for shipment, the inspector shall make the tests to govern the acceptance of the pipe. If any specimen fails to meet the requirements of Sections 5 to 8, inclusive, two additional specimens may be taken, each of which shall conform to the requirements specified.

Inspection. 15. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the pipe is being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified and shall be so conducted as not to interfere unnecessarily with the operation of the works.

STANDARD SPECIFICATIONS
FOR
BRASS PIPE, STANDARD SIZES[1]

Serial Designation: B 43 – 24

These specifications are issued under the fixed designation B 43; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1922; ADOPTED, 1923; REVISED, 1924.

Scope.

1. These specifications cover seamless brass pipe suitable for use in plumbing, boiler feed lines, etc.

MANUFACTURE

Process.

2. The pipe shall be cold-drawn to size.

Annealing.

3. (*a*) The pipe shall be annealed sufficiently to enable it to pass the physical tests herein specified.

(*b*) All pipe shall be annealed sufficiently to prevent cracking. Semi-annealed pipe, which is suitable for ordinary uses, shall be furnished unless otherwise specified.

(*c*) When pipe is required for bending, the purchaser shall so specify, in which case the pipe shall be furnished fully annealed.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

4. The brass shall conform to the following requirements as to chemical composition.

	HOT PIERCED PROCESS.	COLD PROCESS.
Copper, per cent	59.00 – 63.00	65.00 – 68.00
Lead, maximum, per cent	0.50	0.80
Iron, maximum, per cent	0.07	0.07
Zinc	Remainder	Remainder

Sampling.

5. The sample for chemical analysis shall consist of drillings, millings, or clippings taken from the pipes selected for testing purposes, as specified in Section 12, equal quantities being taken from each pipe and thoroughly mixed. Samples so prepared shall be divided into three equal parts, each of which shall be placed in a sealed package, one for the seller, one for the purchaser, and one for an umpire, if necessary.

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee B-2 on Non-Ferrous Metals and Alloys.

PHYSICAL PROPERTIES AND TESTS

Hammering Test. 6. The pipe shall be capable of withstanding the following test without showing cracks or flaws: A piece cut from the ends of the pipe shall be hammered flat on different elements throughout its length so that a gage set at 3 times the thickness of the metal shall pass over the pipe freely throughout the flattened part, except at such points where changes in the elements of flattening take place.

Flattening Test. 7. A test specimen 3 in. in length when split, shall withstand opening out flat without showing cracks or flaws.

Strain Test. 8. A test specimen 3 in. in length shall withstand an immersion in an aqueous mercurous nitrate solution containing 100 g. of mercurous nitrate and 13 cc. of nitric acid (sp. gr. 1.42) per liter of solution for 15 minutes, without cracking.

Threading Test. 9. The pipe shall withstand threading in a satisfactory manner.

Bend Test. 10. In the case of pipe for bending, annealed full sections of the pipe shall withstand being bent cold through 180 deg. without cracking on the outside of the bent portion around a pin the diameter of which is $1\frac{1}{2}$ times the inside diameter of the pipe. This test shall be in addition to the tests specified in Sections 6 to 9, inclusive.

Hydrostatic Test. 11. Each pipe shall withstand, without showing weakness or defects, an internal hydrostatic pressure sufficient to subject the material to a fiber stress of 7000 lb. per sq. in., determined by the formula for thin hollow cylinders under tension:

$$P = 2\frac{tS}{D}$$

in which P equals the pressure in pounds per square inch, t equals the thickness of wall in inches, D equals the outside diameter of the pipe in inches, and S equals the allowable unit stress of the material = 7000 lb. per sq. in. No pipe shall be tested beyond a pressure of 1000 lb. per sq. in. unless so specified.

Number of Tests. 12. A sufficient number of pipe shall be taken at random to constitute 0.5 per cent of the shipment. One flattening, one strain, and one threading test shall be made on each pipe so selected.

DIMENSIONS AND PERMISSIBLE VARIATIONS

Standard Weights. 13. The standard weights and dimensions for pipe of various outside diameters are given in Table I.

Permissible Variations. 14. (*a*) No single piece of pipe that exceeds the calculated weight by more than 5 per cent will be accepted. One cubic inch of the material is assumed to weigh 0.307 lb.

(*b*) The weight of the pipe shall vary not more than the following percentages from the weight specified in Section 13: Pipe 6 in. or less in diameter, 5 per cent; pipe from 6 to 8 in. in diameter, 7 per cent; pipe over 8 in. in diameter, 8 per cent.

WORKMANSHIP AND FINISH

15. (*a*) The pipe shall be round and of uniform thickness throughout. They shall be free from cracks, seams, slivers, scale and other surface defects. **Workmanship.**

TABLE I.—STANDARD WEIGHTS AND DIMENSIONS FOR BRASS PIPE.

Size of Pipe, in.	Outside Diameter, in.	Standard Pipe		Extra Strong Pipe	
		Thickness, in.	Nominal Weight, lb. per foot of length	Thickness, in.	Nominal Weight, lb. per foot of length
⅛	0.405	0.0620	0.246	0.100	0.353
¼	0.540	0.0825	0.437	0.123	0.593
⅜	0.675	0.0905	0.612	0.127	0.805
½	0.840	0.1075	0.911	0.149	1.19
¾	1.050	0.1140	1.24	0.157	1.62
1	1.315	0.1265	1.74	0.182	2.39
1¼	1.660	0.1460	2.56	0.194	3.30
1½	1.900	0.1500	3.04	0.203	3.99
2	2.375	0.1565	4.02	0.221	5.51
2½	2.875	0.1875	5.83	0.280	8.41
3	3.500	0.2190	8.31	0.304	11.24
3½	4.000	0.2500	10.85	0.321	13.67
4	4.500	0.2500	12.29	0 341	16.41
4½	5.000	0.2500	13.74	0.375	20.07
5	5.563	0.2505	15.40	0.375	22.52
6	6.625	0.2500	18.44	0.437	31.32
7	7.625	0.2815	23.92	0.500	41.23
8	8.625	0.3125	30.05	0.500	47.02
9	9.625	0.3440	36.94	0.500	52.81
10	10.750	0.3655	43.91	0.500	59.32

(*b*) The thickness at any point shall not be less than that specified in Section 13 by more than the following percentages: Pipe 6 in. or less in diameter, 5 per cent; pipe from 6 to 8 in. in diameter, 7 per cent; pipe over 8 in. in diameter, 8 per cent.

16. All pipes shall be acid cleaned after the final annealing. **Finish.**

INSPECTION AND REJECTION

17. (*a*) When the pipe is finished, and ready for shipment, the inspector shall make the tests to govern the acceptance of the pipe. If any specimen fails to meet the requirements of Sections 6 to 11, inclusive, two additional specimens may be taken, each of which shall conform to the requirements specified. **Rejection.**

(*b*) Pipes that show non-uniform annealing under handling shall be rejected from the lot.

Inspection.

18. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the pipe is being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified and shall be so conducted as not to interfere unnecessarily with the operation of the works.

STANDARD SPECIFICATIONS
FOR
BRASS FORGING ROD[1]

Serial Designation: B 15 – 18

These specifications are issued under the fixed designation B 15; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1917; ADOPTED, 1918.

These specifications were approved June 8, 1925, as "Tentative American Standard" by the American Engineering Standards Committee.

Scope.

1. These specifications cover brass rods of any specified cross-section capable of being readily forged hot, and easily machined (Note 1).

MANUFACTURE

Process.

2. The rods may be manufactured either by hot rolling or extrusion, and may be finished by cold drawing if necessary to meet the requirement for size.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

3. The brass shall conform to the following requirements as to chemical composition:

Copper	58.5 – 61.5 per cent.
Lead	1.5 – 2.5 "
Iron	not over 0.15 "
Materials other than copper, lead and zinc	" " 0.35 "
Zinc	remainder.

Chemical Analyses.

4. Analyses may be made on each lot of 5000 lb. or less. Drillings or millings shall be made from at least four separate rods, equal quantities being taken from each rod and thoroughly mixed. Samples so prepared shall be divided into three equal parts, each of which shall be placed in a sealed package, one for each party and one for an umpire, if necessary.

Check Analyses.

5. (*a*) Analyses of separate rods may be made by the purchaser. The copper and lead contents thus determined shall lie within the following limits:

Copper	57.9 – 62.1 per cent
Lead	1.2 – 3.0 "

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee B-2 on Non-Ferrous Metals and Alloys.

(*b*) In case of dissatisfaction, the rod or rods shall be sampled in the presence of representatives of both parties. The thoroughly mixed sample shall be divided into three equal parts, each of which shall be placed in a sealed package, one for each party and one for an umpire, if necessary.

PHYSICAL PROPERTIES AND TESTS

Flattening Tests.

6. Specimens cut from rods or bars and having a length equal to the diameter of the specimen, shall stand flattening in an axial direction while hot, until reduced to 20 per cent of their original length, without cracking.

Number of Tests.

7. (*a*) One flattening test shall be made from each lot of 2000 lb. or fraction thereof.

(*b*) In case of failure of any test specimen representing a lot, two additional specimens shall be chosen, each of which shall conform to the requirement specified in Section 6.

PERMISSIBLE VARIATIONS IN DIMENSIONS

Dimensional Variations.

8. (*a*) The diameter of round sections, or the distance between parallel faces in the case of other sections, shall not vary from that specified more than the following:

Diameter, or Distance between Parallel Faces.	Permissible Variation, in.
Up to $\frac{1}{2}$ in., incl.	±0.005
Over $\frac{1}{2}$ to 1 in., incl.	±0.008
Over 1 to $2\frac{1}{2}$ in., incl.	±0.010
Over $2\frac{1}{2}$ in.	±0.015

(*b*) In the case of special shapes, the permissible variations shall be agreed upon according to the requirements.

Lengths.

9. Stock lengths for all rods from $\frac{1}{4}$ to 1 in., inclusive, in diameter or thickness shall be supplied by the manufacturer as follows:

(*a*) When ordered in 12-ft. lengths, no lengths less than 8 ft.; when ordered in 10-ft. lengths, no lengths less than 6 ft.; when ordered in 8-ft. lengths, no lengths less than 6 ft.; when ordered in 6-ft. lengths, no lengths less than 4 ft.

(*b*) When ordered in the lengths given above, the weight of lengths less than the length ordered shall not exceed 40 per cent of any one shipment.

(*c*) For rods over 1 in. up to and including 2 in. in diameter

or thickness, the lengths shall be random lengths from 4 to 10 ft.; for rods over 2 in. in diameter or thickness, special lengths are required, but no length shall be less than 4 ft.

WORKMANSHIP AND FINISH

Finish. 10. The rods shall be free from injurious surface defects and shall have a workmanlike finish. They shall be substantially straight.

INSPECTION AND REJECTION

Inspection. 11. The manufacturer shall afford the inspector representing the purchaser, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications.

Rejection. 12. Material which fails to conform to these specifications will be rejected and the manufacturer shall be notified.

EXPLANATORY NOTE

NOTE 1.—The material intended to be covered by these specifications exhibits a very considerable variation in properties with slight changes in composition. Its strength, stiffness and ability to stand forging operations are in inverse proportion to the copper content; so also is the amount of lead which the alloy can contain without producing hot shortness. Toughness, on the other hand, is directly proportional to the copper content.

STANDARD SPECIFICATIONS
FOR
FREE-CUTTING BRASS ROD FOR USE IN SCREW MACHINES[1]

Serial Designation: B 16 – 18

These specifications are issued under the fixed designation B 16; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1917; ADOPTED, 1918.

These specifications were approved June 8, 1925, as "Tentative American Standard" by the American Engineering Standards Committee.

Scope.

1. These specifications cover free-cutting brass rods of any specified cross-section, suitable for high-speed screw machine work (Note 1).

MANUFACTURE

Process.

2. The rods shall be finished by cold drawing and straightening, unless otherwise specified.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

3. The brass shall conform to the following requirements as to chemical composition (Note 2):

Copper	60.0 – 63.0 per cent
Lead	2.25 – 3.25 "
Iron	not over 0.15 "
Materials other than copper, lead and zinc	" " 0.25 "
Zinc	remainder.

Chemical Analyses.

4. Analyses may be made on each lot of 5000 lb. or less. Drillings or millings shall be made from at least four separate rods, equal quantities being taken from each rod and thoroughly mixed. Samples so prepared shall be divided into three equal parts, each of which shall be placed in a sealed package, one for each party and one for an umpire, if necessary.

Check Analyses.

5. (*a*) Analyses of separate rods may be made by the purchaser. The copper and lead contents thus determined shall lie within the following limits:

Copper	59.4 – 63.6 per cent.
Lead	1.8 – 3.9 "

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee B-2 on Non-Ferrous Metals and Alloys.

(*b*) In case of dissatisfaction, the rod or rods shall be sampled in the presence of representatives of both parties. The thoroughly mixed sample shall be divided into three equal parts, each of which shall be placed in a sealed package, one for each party and one for an umpire, if necessary.

PHYSICAL PROPERTIES AND TESTS

Bend Tests.

6. Rods or bars shall bend cold through an angle of 120 deg. around a pin the diameter of which is equal to twice the diameter or thickness of the rod or bar, without fracture (Note 3).

Number of Tests.

7. (*a*) One bend test shall be made from each lot of 5000 lb. or fraction thereof.

(*b*) In case of failure of any test specimen representing a lot, two additional specimens shall be chosen, each of which shall conform to the requirement specified in Section 6.

PERMISSIBLE VARIATIONS IN DIMENSIONS

Dimensional Variations.

8. The diameter of round sections, or the distance between parallel faces in the case of other sections, shall not vary from that specified more than the following:

Diameter, or Distance between Parallel Faces.	Permissible Variation, in.
Up to $\frac{1}{2}$ in. incl.	±0.0015
Over $\frac{1}{2}$ to 1 in., incl.	±0.002
Over 1 to $2\frac{1}{2}$ in., incl.	±0.0025
Over $2\frac{1}{2}$ in.	±0.003

Lengths.

9. Stock lengths for all rods from $\frac{1}{4}$ to 1 in., inclusive, in diameter or thickness shall be supplied by the manufacturer as follows (Note 4):

(*a*) When ordered in 12-ft. lengths, no lengths less than 8 ft.; when ordered in 10-ft. lengths, no lengths less than 6 ft.; when ordered in 8-ft. lengths, no lengths less than 6 ft.; when ordered in 6-ft. lengths, no lengths less than 4 ft.

(*b*) When ordered in the lengths given above, the weight of lengths less than the length ordered shall not exceed 40 per cent of any one shipment.

(*c*) For rods over 1 in. up to and including 2 in. in diameter or thickness, the lengths shall be random lengths from 4 to 10 ft.; for rods over 2 in. in diameter or thickness, special lengths are required, but no length shall be less than 4 ft.

WORKMANSHIP AND FINISH

Finish. 10. The rods shall be free from injurious defects, substantially straight and free from kinks and bends, and shall have a bright, smooth surface.

INSPECTION AND REJECTION

Inspection. 11. The manufacturer shall afford the inspector representing the purchaser, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications.

Rejection. 12. Material which fails to conform to these specifications will be rejected and the manufacturer shall be notified.

EXPLANATORY NOTES

NOTE 1.—The material intended to be covered by these specifications is suitable for ordinary manufacturing purposes. In order to machine freely it must contain lead, and possess a considerable degree of temper which is obtained by cold working. The former requirement reduces strength and ductility while the latter adds firmness and stiffness.

NOTE 2.—There are four major constituents encountered in all brass alloys, the control and determination of which present very perplexing problems. They are copper, zinc, lead and iron. The high volatility of zinc, the variations in temperature which occur in the alloying operation, and the variation in the proportion in which it is added to the crucible charge in unalloyed form, causes its proportion in the casting to occasionally fluctuate over wide limits. Except when certain expensive grades of zinc are employed, substantially free from lead, the latter element will also show very considerable variation. Iron is subject to accidental introduction.

On account of the fact that the ordinary crucible charge is only about 200 lb., it is not commercially practicable to determine the four main elements in each cast. On the other hand, the determination by chemical analysis of the constituents of an individual sample from a lot of a given size tells little about the mean values of the proportions, or the extreme variations which exist in the lot. It is proposed, though not as a very satisfactory solution of this problem, to require that a sample composed of four equal portions from four individual pieces be taken to represent the mean composition of a lot, and that

individual samples be permitted to vary between wider limits. It is appreciated that this is not a satisfactory solution of the problem, but no better one has been offered.

There are many uses for which alloys outside of the specified limits are perfectly suitable. The limits given, however, represent standard practice. On the other hand, there are special requirements which cannot be most advantageously satisfied by alloys meeting these specifications.

NOTE 3.—It is desirable that a limit be imposed on the hardness due to cold drawing. It is felt that the bend test proposed accomplishes the purpose as satisfactorily as any other test.

NOTE 4.—It is not commercially practicable to furnish material of this character to specific lengths without great expense, especially in the larger sizes, on account of the small size of billet employed. It is, therefore, necessary to permit considerable latitude in this respect.

STANDARD SPECIFICATIONS FOR CARTRIDGE BRASS[1]

Serial Designation: B 19 – 19

These specifications are issued under the fixed designation B 19; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1918; ADOPTED, 1919.

Scope.

1. These specifications cover sheet brass for making rifle and other small arms cartridge cases.

MANUFACTURE

Material.

2. The brass shall be made from lake or electrolytic copper, meeting the requirements of the Standard Specifications for Lake Copper Wire Bars, Cakes, Slabs, Billets, Ingots, and Ingot Bars (Serial Designation: B 4)[2] or the Standard Specifications for Electrolytic Copper Wire Bars, Cakes, Slabs, Billets, Ingots, and Ingot Bars (Serial Designation: B 5)[3] of the American Society for Testing Materials, and zinc of Grades Nos. 1 or 2 of the Standard Specifications for Spelter (Serial Designation: B 6) of the American Society for Testing Materials.[4]

Scrap.

3. No scrap shall be used except that arising from the manufacture of brass or cases made from materials complying with the requirements of Section 2.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

4. The brass shall conform to the following requirements as to chemical composition:

Copper	66.5 – 69.5	per cent
Lead	not over 0.07	"
Iron	" " 0.05	"
Other materials	" " 0.15	"
Zinc	Remainder.	

Chemical Analyses.

5. Analyses may be made on each lot of 50,000 lb. or less. Drillings or millings shall be made from at least ten separate pieces, equal quantities being taken from each and thoroughly mixed. Samples so prepared shall be divided into three equal

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee B-2 on Non-Ferrous Metals and Alloys.

[2] See p. 515. [3] See p. 520. [4] See p. 524.

parts, each of which shall be placed in a sealed package, one for each party and one for an umpire, if necessary.

Check Analyses.

6. (*a*) Analyses of separate pieces may be made by the purchaser. The copper, lead, and iron contents thus determined shall be as follows:

Copper	66.0 – 70.0	per cent
Lead	not over 0.10	"
Iron	" " 0.08	"

(*b*) In case of dissatisfaction, resampling shall be done in the presence of representatives of both parties. The thoroughly mixed sample shall be divided into three equal parts, each of which shall be placed in a sealed package, one for each party and one for an umpire, if necessary.

PHYSICAL PROPERTIES AND TESTS

Hardness Tests.

7. The brass shall be so annealed that the average of ten Brinell hardness readings from a lot will be within the limits of 51 to 65, using a 10-mm. ball and a pressure of 500 kg. No individual test shall exceed the limits of 50 to 69 (Note 1).

PERMISSIBLE VARIATIONS IN DIMENSIONS

Dimensional Variations.

8. A permissible variation of ±0.002 in. from the specified thickness when measured ½ in. from the edge of the strip will be allowed. The width of the strip may vary ±0.010 in.

Lengths.

9. Cartridge metal may be furnished in coils or flat strips as required. When furnished in flat strips, no strip shall be of less length than 60 per cent of that specified. No lot shall contain more than 40 per cent of such short lengths.

WORKMANSHIP AND FINISH

Finish.

10. The metal shall be free from injurious external and internal defects of a nature which will interfere with the purpose for which it is intended. It shall be well pickled and free from dirt. Strips shall be substantially straight and flat (Note 2).

INSPECTION AND REJECTION

Inspection.

11. The manufacturer shall afford the inspector representing the purchaser, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications.

Rejection.

12. Material which fails to conform to these specifications will be rejected and the manufacturer shall be notified.

EXPLANATORY NOTES

NOTE 1.—A comparative study of Brinell hardness and grain size indicates the following relations:

GRAIN SIZE, MM.	EQUIVALENT BRINELL HARDNESS NUMBER.
0.150	47
0.111	49
0.100	49.7
0.098	50
0.087	51
0.075	52¼
0.060	54¾
0.058	55
0.050	57½
0.044	60
0.040	62½
0.034	65
0.030	68
0.029	69

As it is easier and quicker to take the Brinell hardness than to polish and etch samples for study with the microscope, the Brinell hardness is much to be preferred. Furthermore, through straightening or flattening operations, cartridge metal may be hardened to an appreciable extent without affecting the grain size or producing any noticeable distortion.

Many operators in making rapid determinations of grain size slight the polishing and etch in strong acids, so that it is frequently impossible to distinguish between twinned crystals and separate crystals and a false grain count is obtained.

NOTE 2.—The differentiation between immaterial and injurious defects is a matter which requires a considerable degree of knowledge as to the causes of the various kinds of imperfections which are encountered in material of this character, as well as a thorough understanding of the effects thereof upon its further fabrication and use. In general, two classes may be readily distinguished, namely, those which are imposed and those which are inherent. In the former class are dents and scratches caused by blows or abrasion, and foreign matter which, adhering to the surface of the material, may have been rolled into it. Dents and scratches may be of considerable magnitude and still disappear completely in subsequent operations of fabrication. Similarly the presence of imposed foreign matter may be relatively unimportant. The point to be observed in this connection

is that the presence of this class of defects is indicative of nothing beyond their presence.

Inherent defects are those which occur as a result of the presence either of gas or foreign matter included in the material during the process of casting. Metal is seldom entirely free from such defects and visual evidence of these argues the presence of others not visible. Experience is needed to determine whether any such encountered are of a magnitude and character sufficient to establish a departure from correct casting practice sufficient to disqualify the material.

A third character of defect, and one of a grave nature, is caused by failure to completely remove any piping which may have occurred in casting. The indications of this defect are, however, well pronounced and characteristic.

STANDARD SPECIFICATIONS
FOR
CARTRIDGE BRASS DISKS[1]

Serial Designation: B 20 – 19

These specifications are issued under the fixed designation B 20; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1918; ADOPTED, 1919.

Scope.

1. These specifications cover brass disks for making artillery cartridge cases.

MANUFACTURE

Material.

2. The disks shall be made of cartridge brass conforming to the requirements of the Standard Specifications for Cartridge Brass (Serial Designation: B 19) of the American Society for Testing Materials;[2] except as to dimensions and permissible variations thereof, which shall conform to the requirements specified in Section 3.

PERMISSIBLE VARIATIONS IN DIMENSIONS

Dimensional Variations.

3. (*a*) Variations in dimensions shall conform to the following limits:

Diameter.	Permissible Variation, in.	Gage.	Permissible Variation, in.
Up to 1 in., incl.	± 0.0025	Up to 0.150 in., incl.	± 0.0025
Over 1 to 3 in., incl.	± 0.003	Over 0.150 to 0.300 in., incl.	± 0.003
Over 3 to 6 in., incl.	± 0.004	Over 0.300 to 0.400 in., incl.	± 0.004
Over 6 to 8 in., incl.	± 0.005	Over 0.400 in.	± 0.005
Over 8 in.	± 0.0075		

(*b*) The thickness of disks should be measured not less than ½ in. from the edge and on the diameter at right angles to the direction in which the bar was rolled.

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee B-2 on Non-Ferrous Metals and Alloys.

[2] See p. 650.

STANDARD SPECIFICATIONS
FOR
NAVAL BRASS RODS FOR STRUCTURAL PURPOSES[1]

• Serial Designation: B 21 – 27

These specifications are issued under the fixed designation B 21; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1918; ADOPTED, 1919; REVISED, 1927.

Scope.

1. These specifications cover naval brass rods of any uinform cross-section such as round, hexagonal, square, etc. (Note 1.)

MANUFACTURE

Process.

2. The rods shall be manufactured either by hot rolling or extrusion, finished by such cold drawing as may be required, and straightened.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

3. The brass shall conform to the following requirements as to chemical composition:

Copper	59.0 – 61.0 per cent
Tin	0.5 – 1.0 "
Iron	not over 0.10 "
Lead	" " 0.30 "
Materials other than above	" " 0.10 "
Zinc	Remainder

Chemical Analyses.

4. Analyses may be made on each lot of 5000 lb. or less. Drillings or millings shall be made from at least four separate rods, equal quantities being taken from each rod and thoroughly mixed. Samples so prepared shall be divided into three equal parts, each of which shall be placed in a sealed package, one for each party and one for an umpire, if necessary.

PHYSICAL PROPERTIES AND TESTS

Tension Tests.

5. (*a*) The rods shall conform to the following minimum requirements as to tensile properties:

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee B-2 on Non-Ferrous Metals and Alloys.

Diameter, or Distance between Parallel Faces	Yield Point, lb. per sq. in.	Tensile Strength, lb. per sq. in.	Elongation in 2 in., per cent
Up to 1 in., incl	31 000	62 000	25.0
Over 1 to $2\frac{1}{2}$ in., incl	30 000	60 000	30.0
Over $2\frac{1}{2}$ to $3\frac{1}{2}$ in., incl	25 000	56 000	35.0
Over $3\frac{1}{2}$ in	22 000	54 000	40.0

(*b*) Yield point in tension shall be determined as the stress producing an elongation under load of 0.5 per cent, that is, 0.01 in. in a gage length of 2 in.

Bend Tests. 6. The test specimen shall stand being bent cold through 120 deg. to a radius equal to its diameter, without fracturing.

Strain Tests. 7. The test specimen shall stand an immersion in an aqueous mercurous-nitrate solution containing 100 g. of mercurous nitrate and 13 cc. of nitric acid (sp. gr. 1.42) per liter of solution for 15 minutes, without cracking. (Note 2.)

Test Specimens. 8. (*a*) Tension test specimens shall be as nearly as possible of the same diameter, or distance between parallel faces, as the rods.

(*b*) Bend test specimens may be a piece of the full size rod, or a piece 1 in. in width by $\frac{1}{2}$ in. in thickness. In the case of bend test specimens of rectangular section, the edges may be rounded off to a radius equal to one-fourth of the thickness.

(*c*) Strain test specimens shall be of the full size of the rod, at least 12 in. in length, and without bending, springing, polishing, or any other preparation. At least 9 in. of the length of the specimen shall be immersed in the solution.

Number of Tests. 9. (*a*) Rods shall be grouped into lots of not more than 5000 lb.

(*b*) One tension, one bend, and one strain test specimen shall be cut from one rod for each lot or fraction thereof.

(*c*) If any tension test specimen breaks outside the middle third of the gage length, a retest shall be allowed.

PERMISSIBLE VARIATIONS IN DIMENSIONS

Dimensional Variations. 10. The diameter of round sections, or the distance between parallel faces in the case of other sections, shall not vary from that specified more than the following:

Diameter, or Distance between Parallel Faces	Permissible Variation, in.	
	Rounds	Other Shapes
Up to $\frac{1}{2}$ in., incl	± 0.0015	± 0.003
Over $\frac{1}{2}$ to 1 in., incl	± 0.0020	± 0.004
Over 1 to $2\frac{1}{2}$ in., incl	± 0.0025	± 0.005
Over $2\frac{1}{2}$ in	± 0.0030	± 0.006

11. Rods, when ordered to any length, will be received in stock lengths, unless it is specifically stated that the lengths are to be exact. Stock lengths for all rods from $\frac{1}{4}$ to 1 in., inclusive, in diameter or thickness shall be as follows: **Lengths.**

(*a*) When ordered in 12-ft. lengths, no lengths less than 8 ft.; when ordered in 10-ft. lengths, no lengths less than 6 ft.; when ordered in 8-ft. lengths, no lengths less than 6 ft.; when ordered in 6-ft. lengths, no lengths less than 4 ft.

(*b*) When ordered in the lengths given above, the weight of lengths less than the length ordered shall not exceed 40 per cent of any one shipment.

(*c*) For rods over 1 in. up to and including 2 in. in diameter or thickness, the lengths shall be random lengths from 4 to 10 ft.; for rods over 2 in. in diameter or thickness, special lengths are required, but no length shall be less than 4 ft.

WORKMANSHIP AND FINISH

12. The rods shall be free from injurious defects, substantially straight and free from kinks and bends, and shall have a bright, smooth surface. **Finish.**

INSPECTION AND REJECTION

13. The manufacturer shall afford the inspector representing the purchaser, without charge, all reasonable facilities to satisfy him that the rods are being furnished in accordance with these specifications. **Inspection.**

14. Rods which fail to conform to these specifications will be rejected and the manufacturer shall be notified. **Rejection.**

EXPLANATORY NOTES

NOTE 1.—Material intended to be covered by these specifications is suitable for structural purposes, and may be used as rods, bolts, etc. It is capable of being forged hot, but is not free cutting.

NOTE 2.—Bars which have been properly straightened or sprung will have internal stresses so broken up as not to be in danger of splitting or cracking. The mercurous-nitrate test is designed to determine whether the internal stresses have been properly broken up and rendered safe.

STANDARD SPECIFICATIONS
FOR
SHEET HIGH BRASS[1]

Serial Designation: B 36 – 27

These specifications are issued under the fixed designation B 36; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1920; ADOPTED, 1921; REVISED, 1927.

Scope.

1. These specifications cover commercial sheet brass commonly used for drawing, forming, stamping and bending. It should be understood that they are general. Since high brass is used for many purposes where the requirements of the operations used are too particular to be specified by any of the ordinary physical tests, it is frequently advisable to submit samples or drawings to the manufacturer and secure an adjustment of anneal or temper to suit the actual operations to which the material is to be submitted.

MANUFACTURE

Material.

2. (*a*) Sheet high brass shall be made from Lake or Electrolytic Copper conforming to the requirements of the Standard Specifications for Lake Copper Wire Bars, Cakes, Slabs, Billets, Ingot and Ingot Bars (Serial Designation: B 4)[2] or the Standard Specifications for Electrolytic Copper Wire Bars, Cakes, Slabs, Billets, Ingots, and Ingot Bars (Serial Designation: B 5)[3] of the American Society for Testing Materials,[2] and zinc of Grade 3 of the Standard Specifications for Spelter (Serial Designation: B 6) of the American Society for Testing Materials.[4] Clean new scrap resulting from manufacturing operations upon material complying with these specifications or composed of material of equal purity may be employed. (Note 1.)

(*b*) The brass shall be manufactured by the cold-rolling and annealing process and may be furnished in either the cold-rolled or annealed condition, as required.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee B-2 on Non-Ferrous Metals and Alloys.

[2] See p. 515. [3] See p. 520. [4] See p. 524.

CHEMICAL PROPERTIES

3. The brass shall conform to the following requirements as to chemical composition: **Chemical Composition.**

Copper	64.5 to 67.5 per cent
Lead	not over 0.30 "
Iron	" " 0.05 "
Zinc	remainder
Other impurities	not over 0.10 "

4. Analysis shall be made on each lot of 10,000 lb. or less. Drillings, millings or clippings shall be taken from at least 10 separate coils or pieces. Drillings or millings shall be taken on material thicker than 0.040 in. Clippings may be taken with shears from metal thinner than 0.040 in. Equal quantities shall be taken from each piece and thoroughly mixed together. Samples so prepared shall be divided into three equal parts, each of which shall be placed in a sealed package, one for each party and one for an umpire, if necessary. **Chemical Analyses.**

5. (*a*) Analyses of separate pieces may be made by the purchaser. The copper, lead, and iron determined shall be within the following limits: **Check Analyses.**

Copper	64.00 to 68.00 per cent
Lead	not over 0.35 "
Iron	" " 0.07 "

(*b*) In case of dissatisfaction the metal shall be resampled in the presence of representatives of both parties. The thoroughly mixed sample shall be divided into three equal parts, each one of which shall be placed in a sealed package, one for each party and one for an umpire, if necessary.

TEMPER AND ANNEAL

6. The temper of sheet brass shall be designated as follows: **Temper.**

	Reduction, B. & S. Gage Nos.
Quarter Hard	1
Half Hard	2
Hard	4
Extra Hard	6
Spring	8

7. Annealed sheet brass shall be designated as follows: **Anneal.**

Light Anneal.
Drawing Anneal.
Soft Drawing Anneal.

PHYSICAL PROPERTIES AND TESTS

(*A*) *Hard Brass.*

Hardness Tests, Hard Brass.

8. The average Brinell hardness of 10 samples of cold-rolled brass 0.080 in. or over in thickness shall be within the following limits:

Quarter Hard	75 – 95
Half Hard	95 – 115
Hard	130 – 150
Extra Hard	150 – 170
Spring	160 – 180

Tensile Tests, Hard Brass.

9. The average of tension tests of two samples of cold-rolled brass thinner than 0.080 in. shall conform to the following minimum requirements:

	TENSILE STRENGTH, LB. PER SQ. IN.	ELONGATION IN 2 IN., PER CENT.
Quarter Hard	45 000	27.5
Half Hard	52 500	15.0
Hard	67 500	5.0
Extra Hard	80 000	2.0
Spring	87 500	1.0

(*B*) *Soft Brass.*

Hardness Tests, Soft Brass.

10. The average Brinell hardness of ten samples of annealed brass 0.080 in. or over in thickness shall be as follows:

Light Anneal	65 – 75
Drawing Anneal	55 – 65
Soft Drawing Anneal	47 – 55

Tension Tests, Soft Brass.

11. The average of tension tests of two samples of annealed brass thinner than 0.080 in. shall conform to the following minimum requirements:

	TENSILE STRENGTH, LB. PER SQ. IN.	ELONGATION IN 2 IN., PER CENT.
Light Anneal	45 000	32.0
Drawing Anneal	42 000	38.0
Soft Drawing Anneal	40 000	42.0

PERMISSIBLE VARIATION IN DIMENSIONS

Width.

12. The width of sheared metal shall not vary more than 0.010 in.

Thickness.

13. The standard method of specifying thickness shall be in terms of Brown & Sharpe Gage. When the thickness is specified in either common or decimal fractions of an inch, the tolerances shall be

those of the corresponding group of Brown & Sharpe sizes in the following table:

TABLE I.—PERMISSIBLE VARIATIONS IN THICKNESS, IN.

Thickness		Width, in.			
B. & S. Gage No.	Inch	Up to 6 in., inclusive	Over 6 to 9 in., inclusive	Over 9 to 14 in., inclusive	Over 14 to 20 in., inclusive
0000	0.460	0.0043	0.0045	0.0047	0.0049
000	0.4096	0.0042	0.0044	0.0046	0.0048
00	0.3648	0.0041	0.0043	0.0045	0.0047
0	0.3249	0.0040	0.0042	0.0044	0.0046
1	0.2893	0.0039	0.0041	0.0043	0.0045
2	0.2576	0.0038	0.0040	0.0042	0.0044
3	0.2294	0.0037	0.0039	0.0041	0.0043
4	0.2043	0.0036	0.0038	0.0040	0.0042
5	0.1819	0.0035	0.0037	0.0039	0.0041
6	0.1620	0.0034	0.0036	0.0038	0.0040
7	0.1443	0.0033	0.0035	0.0037	0.0039
8	0.1285	0.0032	0.0034	0.0036	0.0038
9	0.1144	0.0031	0.0033	0.0035	0.0037
10	0.1019	0.0030	0.0032	0.0034	0.0036
11	0.0907	0.0029	0.0031	0.0033	0.0035
12	0.0808	0.0028	0.0030	0.0032	0.0034
13	0.0719	0.0027	0.0029	0.0031	0.0033
14	0.0640	0.0026	0.0028	0.0030	0.0032
15	0.0570	0.0025	0.0027	0.0029	0.0031
16	0.0508	0.0024	0.0026	0.0028	0.0030
17	0.0452	0.0023	0.0025	0.0027	0.0029
18	0.0403	0.0022	0.0024	0.0026	0.0028
19	0.0359	0.0021	0.0023	0.0025	0.0026
20	0.0320	0.0020	0.0021	0.0023	0.0024
21	0.0284	0.0019	0.0020	0.0021	0.0022
22	0.0253	0.0018	0.0019	0.0020	0.0021
23	0.0225	0.0017	0.0018	0.0019	0.0020
24	0.0201	0.0016	0.0017	0.0018	0.0019
25	0.0179	0.0015	0.0016	0.0017	0.0018
26	0.0159	0.0014	0.0015	0.0016	0.0017
27	0.0142	0.0013	0.0014	0.0015	0.0016
28	0.0126	0.0012	0.0013	0.0014	0.0015
29	0.0112	0.0011	0.0012	0.0013	0.0014
30	0.0100	0.0011	0.0012	0.0013	0.0014
31	0.0089	0.0010	0.0011	0.0012	0.0013
32	0.0079	0.0010	0.0011	0.0012	0.0013
33	0.0070	0.0009	0.0010	0.0011	0.0012
34	0.0063	0.0009	0.0010	0.0011	0.0012
35	0.0056	0.0008	0.0009	0.0010	0.0011
36	0.0050	0.0008	0.0009	0.0010	0.0011

14. Metal may be furnished in coils or flat strips as required. Coils shall consist of not more than three lengths, no one of which shall be less than 10 ft. long. When furnished in flat strips a variation of $\frac{1}{16}$ in. over the specified length will be permitted on full-length sheets. **Length.**

15. (*a*) When ordered in lengths over 10 to 12 ft., **Acceptable Short Lengths.**

40 per cent may be 10 ft. and over.
30 " " " 8 to 10 ft.
20 " " " 6 to 8 ft.
10 " " " 4 to 6 ft.

Not more than 40 per cent of any one shipment may be less than the length ordered.

(*b*) When ordered in 10 ft. lengths,

40 per cent may be 8 ft. and over.
30 " " " 6 to 8 ft.
20 " " " 4 to 6 ft.
10 " " " 2 to 4 ft.

Not more than 40 per cent of any one shipment may be less than 10 ft.

(*c*) When ordered in 8 ft. lengths,

30 per cent may be 6 ft. and over.
20 " " " 4 to 6 ft.
10 " " " 2 to 4 ft.

Not more than 30 per cent of any one shipment may be less than 8 ft.

(*d*) When ordered in 6 ft. lengths,

20 per cent may be 4 ft. and over.
10 " " " 2 to 4 ft.

Not more than 20 per cent of any one shipment may be less than 6 ft.

(*e*) When special lengths are required, they shall be specified in the order.

WORKMANSHIP AND FINISH

Finish. 16. The brass shall be free from injurious external and internal defects of a nature which will interfere with the purpose for which it is intended. It shall be well cleaned and free from dirt.

INSPECTION AND REJECTION

Inspection. 17. The manufacturer shall afford the inspector representing the purchaser, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications.

Rejection. 18. Material which fails to conform to these specifications will be rejected and the manufacturer shall be notified.

EXPLANATORY NOTE

NOTE 1.—In the making of brass the best results are obtained if a minimum of one-third of previously alloyed material is used. It is also frequently desirable to employ previously alloyed material composed of copper and zinc in proportions other than provided for in these specifications, sufficient copper and zinc being added as may be required to properly correct the composition.

STANDARD METHODS OF BATTERY ASSAY OF COPPER[1]

Serial Designation: B 34 – 20

These methods are issued under the fixed designation B 34; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1919; ADOPTED, 1920.

These methods were approved June 15, 1921, as "Tentative American Standard" by the American Engineering Standards Committee.

APPROVED BY THE SUPERVISORY COMMITTEE ON STANDARD METHODS OF ANALYSIS, AMERICAN CHEMICAL SOCIETY.

The methods that follow are those originally proposed by Heath,[2] whose work has been checked and elaborated by Keller, Ferguson and others.

The methods are those generally accepted in the United States for standard analysis in all the larger laboratories of both producers and consumers of copper and copper products.

GENERAL INSTRUCTIONS

Sampling Ingots.—Select six ingots at random from the lot. Considering three ingots as a rectangular unit, drill one hole in each ingot, one at the center and one at each end of a diagonal of the rectangle. Drill each hole entirely through the ingot, starting from the bottom. Start the drill on the surface sufficiently to remove the oxide before commencing to collect the drillings for the sample. Run the drill so as to prevent oxidation of the chips. Discard all drillings carrying oxide from the "set," or burned by the drill. Use no lubricant on the drill, and if the sample shows oil or grease, remove this with ether. Sift all drillings on a screen with 250 meshes per sq. cm. in order to remove material which is ground between the drill and sides of the hole. Extract with a strong magnet any iron which

[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee B-2 on Non-Ferrous Metals and Alloys.

[2] Heath, *Transactions*, Am. Inst. Min. Engrs., Vol. 27, pp. 390–400 (1897).

may have come from the drill. Keep the drillings in air-tight bottles.

Weights.—Weights shall be calibrated and frequently rechecked. It is recommended[1] to use a special 5-g. brass weight in weighing the samples and to have the weight of the sample always within 5 mg. of 5 g. When the cathode with its deposit is finally weighed the identical weights are to be used with which the cylinder was tared, plus the special 5-g. brass weight. This brings all the change or deficiency in the final weight on a small fractional weight and the beam and rider.

ASSAY OF ELECTROLYTIC AND LOW-RESISTANCE LAKE COPPER

The method described below is applicable to such grades of electrolytic and low-resistance lake copper as are covered by the Standard Specifications for Lake Copper Wire Bars, Cakes, Slabs, Billets, Ingots and Ingot Bars (Serial Designation: B 4)[2] and for Electrolytic Copper Wire Bars, Cakes, Slabs, Billets, Ingots and Ingot Bars (Serial Designation: B 5),[3] of the American Society for Testing Materials. The silver is deposited with the copper and is included as such; when it is desired to correct for the silver this is determined in a larger separate sample and the amount found is deducted from the deposit of copper plus silver.

APPARATUS FOR ELECTROLYSIS

Electrodes.—The electrodes recommended are of the stationary and not of the rotating type, as the stationary require less of the operator's time and there is less chance for erroneous results to be obtained than with the other kind. Rapid and accurate results are obtained with stationary electrodes made from platinum gauze.

Cathodes.—Platinum cathodes may be formed either from plain or perforated sheets, or from wire gauze, and may be either open or closed cylinders. They should give a depositing surface, counting both sides, of approximately 100 sq. cm. Gauze cathodes are recommended, and are best made from gauze containing approximately 400 meshes per sq. cm. (50 meshes per linear inch). The cathode should be stiffened by doubling the gauze for about 3 mm. at the top and at the bottom of the cylinder. The cylinder should be approximately 30 mm. in diameter and 30 mm. in height. The stem should be made

[1] Greenwood, U. S. Metals Refining Co., Personal Communication.

[2] See p. 515. [3] See p. 520.

from 1.14-mm. or 1.29-mm. wire, flattened and electrically welded the entire width of the gauze; the height over all should be approximately 130 mm., and the gauze should be sand blasted.

Anodes.—Spiral platinum anodes should be used, made from 1.02-mm. or 1.14-mm. wire formed into a spiral of 7 turns having a height of approximately 51 mm. and a diameter of 16 mm., the length over all being approximately 145 mm.

SOLUTION REQUIRED

"Assay Solution" for Dissolving.—Mix 300 cc. of H_2SO_4 (sp. gr. 1.84), 210 cc. of HNO_3 (sp. gr. 1.42) and 750 cc. of distilled water.

METHOD

Place 5 g. of the drillings in a tall lipless beaker which is provided with a well-fitting cover glass, and add 42 cc. of "Assay Solution." The electrolysis beakers are from 100–125 mm. tall and 55 mm. in diameter across the bottom, with a total capacity of 225 to 300 cc. After the assays have stood for a few minutes and the action has nearly ceased, place them on a steam bath having a temperature of 80 to 90° C. and allow them to remain there until solution is completed and the red fumes have disappeared. Wash the cover and the sides of the beaker and dilute the solution to 150 cc. and electrolyze, keeping the top of the cathode 5 or 6 mm. below the surface of the solution.

During electrolysis, cover the beakers with two pairs of split watch glasses placed at right angles to each other. For each solution use a current of one ampere at approximately 10 volts, or else use a current of 4 amperes at approximately 10 volts continued for about 4 hours. The latter case requires the use of gauze cathodes. In the former case, it is convenient to start the assays at night; after about 15 hours wash the cover glasses, electrodes and beakers and reduce the current to 0.6 ampere per solution. As soon as the cathodes begin to evolve gas reduce the current to 0.4 ampere per solution. When this occurs take out about 1 cc. of liquid, place it in a depression in a porcelain test plate and add two or three drops of fresh H_2S water. If the slightest discoloration occurs continue the electrolysis, repeating the test until there is no discoloration whatever.[1] If possible the assay should finish without decided evolution of gas.

[1] It has been shown by Heath, *Journal of Industrial and Engineering Chemistry*, Vol. 4, p. 404 (1912), that a few thousandths of a per cent of copper may remain in the solution without being detected by the test on the spot plate. This amount of copper is negligible in many

Without interrupting the current, siphon off the acid solution, at the same time filling the beakers with distilled water. Remove the cathodes quickly and rinse them in distilled water and two successive baths of alcohol. An experienced operator can quickly remove a cathode and immerse it in water without loss. Throw off the excess alcohol by a quick motion of the hand and ignite the remainder by bringing the cathode quickly to the flame of an alcohol lamp; then keep the cathode moving continually while the alcohol burns. Weigh as metallic copper.

Accuracy.—All assays shall be made in duplicate and shall check within an outside limit of 0.015 per cent of copper.

NOTES

Use of the "Assay Solution" prevents a violent reaction and a consequent loss of copper with the vapors. The solution should not be boiled, since this likewise may cause a loss of copper.

By the use of rotating anodes, gauze or perforated electrodes or the Frary solenoid, it is possible to use a high current density and to reduce the time required for depositing the copper to about four hours. Good results can be obtained by experienced workers, but there is much more chance for error. The slow or over-night method, which is more certain and which requires less of the operator's time, is therefore recommended.

The deposition of the silver with the copper is said to work well up to the limit of 0.3 per cent silver, that is, 100 oz. per ton.

The method of burning off the alcohol in the flame of an alcohol lamp dries the cathode without causing oxidation, whereas drying in an oven to 100° C. generally causes increase in weight.

ASSAY OF LOW-GRADE OR CASTING COPPER

For all grades of copper which are not included in the specifications of the American Society for Testing Materials, previously referred to, as Electrolytic and Low-Resistance Lake Copper, the procedures given below are recommended. These brands may contain a considerable amount of arsenic and some antimony, tellurium, bismuth and nickel. (See Notes.)

SOLUTION REQUIRED

"Assay Solution" for Dissolving.—Mix 300 cc. of H_2SO_4 (sp. gr. 1.84), 210 cc. of HNO_3 (sp. gr. 1.42) and 750 cc. of distilled water.

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instances, but when necessary to make exact determinations, as in the complete analysis of copper, make the solution, after electrolysis, slightly alkaline, neutralize with HCl (sp. gr. 1.19), adding 3 cc. excess, evaporate to 50 cc. and precipitate with H_2S. Filter off the copper sulfide, treat with HNO_3 and H_2SO_4, deposit the small amount of copper from the solution by electrolysis and add it to that obtained in the original determination.

METHOD I

Carry out the assay exactly as given for Electrolytic and Low-Resistance Lake Copper. Place the cathode in a clean beaker, cover with a watch glass perforated with a small hole just large enough to accommodate the stem of the electrode, add 42 cc. of "Assay Solution" and water enough to cover the sheet. Let it stand upon the steam bath until the coating is dissolved. Re-electrolyze in the regular manner.

METHOD II[1]

Dissolve a 5-g. sample in 42 cc. of the "Assay Solution" and evaporate until all the HNO_3 is expelled. Redissolve in 70 cc. of water and add 3 cc. of ferric nitrate solution (1 cc. = 0.01 g. of iron). Transfer the solution to a lipped beaker and place the original beaker under a funnel fitted with a small filter paper. Precipitate the iron from the hot liquid by ammonia, filter and wash out salts. Place the solution on a hot plate to concentrate, reprecipitate the hydroxide from dilute H_2SO_4 in a very small volume of solution and add the filtrate to the main solution. Reprecipitate the hydroxide once more from dilute H_2SO_4, filter, wash thoroughly and add the filtrate to the main solution. Make acid with dilute H_2SO_4 and add 2 cc. of HNO_3 (sp. gr. 1.42). Deposit the copper as in the method for Electrolytic and Low-Resistance Lake Copper.

METHOD III[2]

(FOR COPPER CONTAINING ONLY TRACES OF ANTIMONY OR BISMUTH BUT SUFFICIENT SELENIUM OR TELLURIUM TO INTERFERE.)

Dissolve the 5-g. sample in 42 cc. of "Assay Solution" and evaporate until fumes appear, or until the residue is white. Redissolve in 60 cc. of water and saturate the boiling hot solution for 10 minutes with SO_2 gas, removing the solution from the lamp when the gas is started. The gas may be generated by dropping cold saturated sodium sulfite solution into strong H_2SO_4. It is also conveniently obtainable in cylinders which are fitted with a valve. Let the precipitate settle for a few hours, filter and wash with a little hot water. Boil the filtrate gently to remove most of the SO_2 gas. Ignite the filter in a porcelain crucible to volatilize the selenium and tellurium, redis-

[1] Heath (Senter modified), *Journal*, Am. Chem. Soc., Vol. 26, p. 1123 (1904).

[2] Heath, *Ibid.*, Vol. 26, p. 1123 (1904); Keller, *Transactions*, Am. Inst. Min. Engrs., p. 2098 (1913), *Bulletin No. 80.*

solve the oxidized residue in 1.5 to 2 cc. of HNO_3 and add to the main solution. Deposit the copper as in the method for Electrolytic and Low-Resistance Lake Copper.

NOTE

The selenium is said to be carried down by SO_2 as a selenide of silver, but the roasting sufficiently removes the elements selenium and tellurium. When silver is to be removed, the selenium, etc., are thrown down with the silver by the SO_2 gas and the precipitation of silver is then completed by the addition of chlorides or HCl.

METHOD IV[1]

(FOR COPPER HIGH IN ARSENIC ONLY.)

Modification A.—Dissolve the sample in 42 cc. of the "Assay Solution" in the regular way and add 5 g. of ammonium nitrate. Electrolyze as usual.

Modification B.—Dissolve the sample in 60 cc. of the "Assay Solution" instead of 42 cc. Electrolyze as usual.

Accuracy.—All assays shall be made in duplicate and shall check with an outside limit of 0.015 per cent of copper.

NOTES

It has been recommended[2] to use with solutions of the Low-Grade or Casting Copper about 2 cc. of an addition agent prepared by boiling "lard oil" with strong HNO_3, cooling and removing the grease. This, it is said, will permit the use of high current densities and yet allow the copper to be deposited pure and bright. Moreover, it is said that arsenic and antimony, when present, do not contaminate the copper. It seems probable,[3] however, that copper deposited from such solutions is not quite pure and that it is more accurate to purify the cathode deposit (Method I) or to give a preliminary treatment to the solution (Method II).

Method II is recommended in preference to Method I, which should be used only in the presence of small amounts of impurities.

In Method IV for copper high in arsenic, *Modification B* is to be preferred.

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[1] *Modification A.*—Heath, *Journal*, Am. Chem. Soc., Vol. 26, p. 1124 (1904); *Modification B.*—Heath, *Journal of Industrial and Engineering Chemistry*, Vol. 3, p. 75 (1911).

[2] Guess, *Transactions*, Am. Inst. Min. Engrs., Vol. 36, p. 605 (1905).

[3] Keller, *Ibid.*, p. 2099 (1913), *Bulletin No. 80*; Heath, *Journal of Industrial and Engineering Chemistry*, Vol. 3, p. 75 (1911).

STANDARD METHODS
OF
CHEMICAL ANALYSIS OF PIG LEAD[1]

Serial Designation: B 35 – 24

These methods are issued under the fixed designation B 35; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1919; ADOPTED, 1920; REVISED, 1924.

A. DETERMINATION OF SILVER

Weigh .100 g. of the sample into a 3-in. scorifier and heat in a muffle furnace until the assay "covers." Pour into an iron mold and allow to cool. Free the resulting lead button from PbO, scorify again and pour as before. The button last obtained should not weigh over 20 g. and can be cupelled directly. Weigh the silver button obtained upon an assay balance.

NOTE

If the amount of silver is large, the button should be examined for gold, in the usual manner.

B. DETERMINATION OF BISMUTH

SOLUTIONS REQUIRED

Sodium Carbonate.—Dissolve 100 g. Na_2CO_3 in a liter of distilled water.

Ammonium Carbonate.—Make a half saturated solution.

Alkaline Sulfide Wash Solution.—Dissolve 200 g. of KOH in a liter of distilled water and mix one part of this solution with 4 parts of H_2S water.

METHOD

(*a*) *Determination for Ordinary Amounts of Bismuth.*

Dissolve 20 g. of the sample in a 400-cc. beaker with 100 cc. of HNO_3 (1:4), with the aid of heat. When solution is complete, add dilute ammonia (1:2) with constant stirring, drop by drop from a burette, until a faint opalescence appears. If an actual precipitate

[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee B-2 on Non-Ferrous Metals and Alloys.

is formed, redissolve by the addition of a small amount of HNO_3 (1:4) and repeat the addition of ammonia. Now add 5 cc. of HCl (1:9), fill the beaker with hot water, bring to boiling, and allow to stand on a steam bath for two hours. The assay, while standing, must not reach the boiling temperature. Filter through a 7-cm. paper. Transfer the precipitate completely to the paper by means of a "policeman" and wash twice with hot water. Carefully examine the filtrate, washings, and any decanted liquid and reject if clear. Dissolve the precipitate by dropping around the edges, from a 5-cc. pipette, 5 cc. of boiling HCl (1:9), receiving the solution in the original beaker. Wash the paper thoroughly with hot water, fill the beaker with water, bring to boiling, and allow to stand as before. Filter the bismuth oxychloride upon a weighed Gooch crucible, wash thoroughly with water, once with alcohol, once with ether, and dry upon the hot plate. Cool and weigh.

NOTE

If time permits it is convenient to allow the assay to stand over night. In that case, the precipitate of bismuth oxychloride generally settles so completely that the clear supernatant solution can be decanted.

(*b*) *Determination for Amounts of Bismuth Smaller than Can be Determined by* (*a*).

Dissolve 100 g. of the sample in 500 cc. of dilute HNO_3 (1:4). When solution is complete, allow to cool and add Na_2CO_3 solution little by little until a slight permanent precipitate has formed. Then add 50 cc. of the Na_2CO_3 solution, bring to boiling, allow to stand warm until the supernatant liquor is clear again, filter and reject the filtrate. Dissolve the precipitate without washing by slowly pouring hot HNO_3 (1:4) around the edges of the filter paper, using no more acid than necessary. Wash the paper once with hot water and determine bismuth in the filtrate as described in (*a*).

NOTE

When the sample contains a small amount of bismuth, it is often difficult to ascertain when the correct amount of ammonia has been added to the nitrate solution. In this case, place a small piece of litmus paper in the solution, and add the ammonia very gradually until the litmus paper indicates a neutral reaction.

(*c*) *Determination of Bismuth in Samples Containing Appreciable Amounts of Tin and Antimony.*

Use a piece of litmus paper as in Note under (*b*), and after the first precipitation of bismuth oxychloride has been filtered off and washed (see (*a*)) proceed as follows: Dissolve the bismuth by dropping around the edges of the paper 10 cc. of boiling HCl (1:2), receiving the

solution in the original beaker. Discard the paper after washing. Dilute the solution to about 200 cc. with fresh H_2S water and then pass H_2S gas through the hot solution for 15 minutes. Filter and wash with hot water. Remove any tin or antimony present by washing three times with alkaline sulfide wash solution. Wash the precipitate again with hot water, place it, together with the filter paper, in a 100 cc. beaker, add 20 cc. of HNO_3 (1:4), boil until sulfides are completely dissolved and the paper well pulped. Filter the solution, receiving the filtrate in the original beaker, and wash well. Determine bismuth in the filtrate as in (*a*).

NOTES

When the sample contains comparatively large amounts of tin or antimony, the residue left after the solution of the lead in the nitric acid obscures the opalescence found upon the addition of ammonia.

If the original sample contains more than 0.25 per cent of bismuth, it is preferable to use only a 10-g. charge.

C. DETERMINATION OF ARSENIC

METHOD

Dissolve 111.11 g. of the sample in 550 cc. of HNO_3 (1:4). When solution is complete wash into a graduated liter flask, add 75 cc. of H_2SO_4 (1:1), cool, and make up to the mark with water. Transfer to a large beaker, rinsing out the flask with 25 cc. of water. Mix thoroughly, allow to settle and filter off 900 cc., equivalent to a 100-g. charge. Evaporate in a large porcelain dish until only enough H_2SO_4 is left to moisten the residue. When cool, wash into a small distilling flask with 60 cc. of HCl (sp. gr. 1.19) and 20 cc. of water, cleaning the dish carefully. Add 10 g. of ferrous sulfate and distill, boiling to as small a volume as possible. When cool add 50 cc. more of HCl (sp. gr. 1.19) and redistill. Pass H_2S gas through the cold distillate for 45 minutes. Filter, and weigh the As_2S_3 on a Gooch crucible, washing with cold water, alcohol and CS_2. After drying and weighing, redissolve with $(NH_4)_2\,CO_3$ solution and reweigh the Gooch crucible, calculating the loss in weight to arsenic.

NOTE

The 25 cc. of water added is equivalent to the volume of precipitated lead sulfate.

D. DETERMINATION OF REMAINING METALS

SOLUTIONS REQUIRED

Tartaric Acid.—Dissolve 50 g. of tartaric acid in 250 cc. of distilled water to which has been added 250 cc. HCl (sp. gr. 1.19).

METHOD

Dissolve 222.23 g. of the sample in 1100 cc. of HNO_3 (1:4), using a 1300-cc. beaker. When solution is complete examine for color and turbidity. If clear, wash the solution at once into a 2000-cc. graduated flask. In case of a residue (Note 1), however, dilute to about 1100 cc. and allow to stand until the supernatant liquor is clear. Decant as much as possible into a 2000-cc. flask, filter the remainder and receive the filtrate in the same flask. Wash the precipitate well and then place it, together with the filter paper, in a 100-cc. beaker and add 20 cc. of the tartaric acid mixture. Heat to boiling and when the paper is well pulped allow to digest warm for 30 minutes. Now add 50 cc. of hot water, filter and wash. (Note 2.) Carefully dry the residue and ignite. If any appreciable residue remains, brush it into a small silver dish containing 1 g. of molten KOH. Fuse for 5 minutes, and after cooling dissolve in as little hot water as possible and add to the above mentioned tartaric acid filtrate. Render this solution just alkaline with ammonia and then just acid with HCl, and saturate hot with H_2S gas. After digesting for 30 minutes on the steam bath, pass H_2S through the solution again for 15 minutes. Filter and wash with slightly acidified H_2S water. Reject the filtrate. Wash the sulfides from the paper into the original beaker and add 5 cc. of KOH solution (1:5) for every 25 cc. volume present. Digest hot for 5 minutes and filter through the original paper into a small flask graduated to 110 cc. After washing with H_2S water containing a little of the KOH solution, cool the filtrate and make up to the mark. Mix and reserve 100 cc. as alkaline sulfide solution No. 1. The precipitate may be discarded.

Add slowly to the main solution in the 2000-cc. flask 150 cc. of H_2SO_4 (1:1). After cooling and filling up to the mark, pour into a clean 3-liter flask provided with a rubber stopper. Rinse the flask out with 50 cc. of water, which is equivalent to the volume of lead sulfate present and is added to the portion. After mixing thoroughly by shaking, allow the precipitate to settle and filter off 1800 cc. of the liquid. This is equivalent to a 200-g. charge. Place this in a No. 9 porcelain evaporating dish and evaporate, first over a free flame and later on the hot plate until only enough H_2SO_4 is left to moisten the residue remaining. Add 50 cc. of water and, after digesting warm for a short time, wash the solution into a 250-cc. beaker, cleaning the dish carefully. Allow the solution to digest on the steam bath for 4 or 5 hours. (Note 3.) Then filter, wash and evaporate the filtrate to 200 to 250 cc. Place any residue (Note 4), together with the filter paper, in a 100-cc. beaker and treat with 20 cc. of the tartaric acid

mixture. Boil for 5 minutes, dilute with 50 cc. of hot water and filter. Make the filtrate alkaline with ammonia and just acid with HCl, and obtain the tin, antimony and arsenic as previously described, reserving the whole of the alkaline sulfide solution as solution No. 2. Reject the sulfide residue.

To filtrate from the lead sulfate, add ammonia until the neutral point is reached, and then for every 50 cc. of the solution present add 2 cc. of HCl (sp. gr. 1.19). Pass H_2S gas into the hot solution until saturated, digest for 30 minutes on the steam bath and again pass H_2S gas into the solution. Filter and wash with H_2S water slightly acidified. (Note 5.) Separate tin, antimony and arsenic in the precipitate with KOH solution as usual, obtaining an alkaline sulfide solution No. 3. (Note 6.)

To sum up, three alkaline sulfide solutions have been obtained, containing tin, antimony and arsenic, a precipitate of metallic sulfides containing copper, lead, etc., and a solution containing iron, zinc, nickel, etc.

NOTES

1. A residue indicates the presence of antimony, tin, possibly arsenic, or sulfur as lead sulfate.

2. It has been found that even this treatment occasionally fails to dissolve stannic acid completely.

3. If it is preferred, allow the solution to stand over night to insure the complete solution of all soluble salts.

4. Any residue of lead sulfate may contain some tin, antimony, or possibly arsenic.

5. The filtrate will contain any iron, zinc, nickel, cobalt and manganese; while in the precipitate will be found any copper, cadmium, lead, silver, bismuth, tin, antimony and arsenic.

6. When separating the sulfides of arsenic, antimony and tin from sulfides of copper, lead, etc., it is necessary to wash all the sulfides back into the beaker in which they were precipitated. These sulfides sometimes cling so tenaciously to the paper that in dislodging them more water than the 25 cc. specified is required. In this case allow the sulfides to settle and then decant the clear supernatant liquor through the filter until the volume is reduced to 25 cc. Before rejecting the decanted fluid always test with H_2S water.

In washing sulfide precipitates with water, much trouble is experienced from the tendency of the precipitate to pass through the filter in the colloidal form. This is particularly true in washing sulfides that have been digested with KOH. Time and trouble will be saved by washing all the sulfides precipitated from mineral acid solutions with H_2S water containing a little of the acid in which they were precipitated. The same is true of sulfides precipitated in or filtered from an alkaline solution.

When working with alkaline solutions in which tin is to be determined, avoid the use of Jena or other glass that contains zinc. The zinc content of the glass may influence the result.

DETERMINATION OF ANTIMONY AND TIN

SOLUTIONS REQUIRED

Potassium Iodide.—Dissolve 100 g. in a liter of distilled water.

Standard Sodium Thiosulfate.—Dissolve 24.8 g. of $Na_2S_2O_3 \cdot 5H_2O$ in 1000 cc. of distilled water, and allow to stand for 24 hours. Standardize against Antimony Metal c. p., using the same quantity of reagents and same procedure as under method. Each cubic centimeter is equivalent to approximately 0.006 g. of antimony.

METHOD

Wash the alkaline sulfide solutions Nos. 1, 2, and 3 into a 600-cc. beaker, and acidify with 5 cc. of HNO_3 (sp. gr. 1.42) and 20 cc. of HCl (sp. gr. 1.19). Evaporate the solution to dryness on the steam bath. Dissolve the residue in 200 cc. of water, add 10 g. of oxalic acid and 10 g. of ammonium oxalate and heat the solution until it is clear. Then pass H_2S gas through the boiling solution for 45 minutes. Filter off the precipitate, consisting of arsenic and antimony sulfides, and wash with hot water. Determine tin electrolytically in the filtrate, continuing the electrolysis until all the oxalic acid is decomposed and the solution becomes alkaline. Dissolve the deposit on the cathode with a small amount of HCl and examine qualitatively for tin.

Dissolve the sulfides of arsenic and antimony in KOH as usual, collecting the filtrate in a 500-cc. Erlenmeyer flask. Add 50 cc. of HCl (sp. gr. 1.19) and boil the solution until about 30 cc. are left. Expel the arsenic as chloride. Now oxidize the solution with a pinch of $KClO_3$ and boil until no more chlorine remains. Cool and add 5 cc. of potassium iodide solution. Titrate the liberated iodine with 0.1 *N* sodium thiosulfate solution, using carbon disulfide as an indicator.

DETERMINATION OF COPPER AND CADMIUM

SOLUTIONS REQUIRED

Sodium Chloride (*Solution No. 1*).—Dissolve 1 g. of NaCl in 100 g. of distilled water.

Sodium Chloride (*Solution No. 2*).—Dissolve 10 g. of NaCl in 100 g. of distilled water.

Standard Potassium Cyanide.—Dissolve 2 g. of KCN in a liter of distilled water and standardize against a known amount of copper as treated in the analysis.

Sodium Carbonate (*Solution No. 1*).—Dissolve 50 g. of Na_2CO_3 in 1 liter of distilled water.

Sodium Carbonate (*Solution No. 2*).—Dissolve Na_2CO_3 in distilled water to saturation.

METHOD

(a) Determination Where Copper Exceeds 0.0025 per cent.

Place the filter containing the sulfides in a 100-cc. beaker and add 20 cc. of HNO_3 (1:4). Heat with occasional stirring until the paper is thoroughly pulped and the sulfides are completely dissolved. Filter into a 250-cc. beaker. Dry the residue, which generally contains a small amount of copper, ignite in a porcelain crucible, boil with 5 cc. of HNO_3 (1:1), and wash into the main portion, keeping the volume below 100 cc. Render it strongly alkaline with ammonia, and add 5 g. of potassium cyanide, then saturate it in the cold with H_2S gas. (Note 1.) Filter the solution and evaporate the filtrate to a volume of 20 to 30 cc. in a 4-in. porcelain casserole. Boil until solution is complete. Add 20 cc. of H_2SO_4 (1:1) and evaporate the solution under a hood until dense fumes of H_2SO_4 escape. Cool, dilute, and warm until copper sulfate is all dissolved. Now filter, if necessary, into a 200-cc. beaker, render just alkaline with ammonia, make acid by the addition of 3 cc. of HNO_3 per 100 cc. of solution, and electrolyze for copper.

Dissolve the precipitate of sulfides in the usual manner with 20 cc. of HNO_3 (1:4). Add 1 cc. of NaCl solution No. 1 to the solution, still containing the pulped filter, and digest for 30 minutes. Filter off the AgCl, wash and reject. Make the filtrate, not exceeding 100 cc., alkaline with a slight excess of Na_2CO_3 and add 5 g. of KCN. Digest for 1 hour. Filter and wash with Na_2CO_3 solution No. 1. Reject the precipitate of bismuth. Now add a few cubic centimeters of ammonium sulfide solution to the filtrate to precipitate any cadmium as yellow cadmium sulfide. Filter upon a weighed Gooch crucible and weigh as cadmium sulfide. (Note 2.)

NOTES

1. Copper remains in the solution, while lead, silver, bismuth and cadmium are precipitated.

2. If an appreciable amount of cadmium sulfide is found, it should be converted to and weighed as cadmium sulfate, according to method for cadmium under Standard Methods of Chemical Analysis of Spelter (Serial Designation: B 38) of the American Society for Testing Materials.[1]

(b) Determination Where Copper is Less than 0.0025 per cent.

Place the paper containing the sulfides in a porcelain crucible, dry carefully and ignite. When the carbon has been all burned off, cool and dissolve the residue in 5 to 10 cc. of HNO_3 (1:1). After evaporating to a volume of 1 to 2 cc., add 1 cc. of H_2SO_4 (1:1). Then evaporate

[1] See p. 679.

the solution until fumes appear, cool, dilute, add a few drops of NaCl solution No. 2, and filter off the lead sulfate and silver chloride. Again evaporate the filtrate until fumes of H_2SO_4 appear, and when cold dilute and neutralize with Na_2CO_3 solution No. 2. Then add about six drops of concentrated ammonia and titrate the solution with standard KCN solution until the blue color is discharged.

The cadmium can be obtained by making this solution, titrated for copper, strongly alkaline, diluting a little, and adding 5 g. of KCN. Saturate the solution cold with H_2S gas, filter, discard the filtrate and treat the precipitate for cadmium as described in Method (*a*).

DETERMINATION OF IRON

METHOD

Evaporate the filtrate containing iron, zinc, etc., to 100 cc. and oxidize with a few drops of HNO_3. Separate the iron with ammonia as usual, making two separations, and receive the filtrate in a 500-cc. Erlenmeyer flask. Redissolve the iron hydroxide with hot HCl (1:1) or dilute H_2SO_4 and determine the iron volumetrically by any of the standard methods.

DETERMINATION OF ZINC

SOLUTIONS REQUIRED

Nitric Acid (1 : 4).—Mix 200 cc. of HNO_3 (sp. gr. 1.42) with 800 cc. of distilled water.

Sulfuric Acid (1 : 1).—Carefully pour, with stirring, 500 cc. of H_2SO_4 (sp. gr. 1.84) into 500 cc. of distilled water.

Acidulated Hydrogen Sulfide Water.—Add 20 cc. of HCl (sp. gr. 1.19) to 1000 cc. of distilled water and saturate with hydrogen sulfide.

Ammonium Thiocyanate Solution (2-per-cent).—Dissolve 20 g. of NH_4CNS in 1000 cc. of distilled water.

Hydrochloric Acid (1 : 3).—Mix 100 cc. of HCl (sp. gr. 1.19) and 300 cc. of distilled water.

Standard Zinc Solution (0.1 mg. of zinc per cc.).—Dissolve exactly 0.1 g. of U. S. Bureau of Standards pure zinc in 5 cc. of HCl (sp. gr. 1.19) and dilute to exactly 1000 cc. with distilled water.

Potassium Ferrocyanide Solution.—Dissolve 34.8 g. of $K_4Fe(Cn)_6 \cdot 3H_2O$ in 1000 cc. of distilled water.

METHOD

Dissolve 222.23 g. of the sample in 1100 cc. of HNO_3 (1 : 4), using a 1300-cc. beaker. When the lead is dissolved, transfer the

solution to a 2000-cc. graduated flask and add slowly 150 cc. of HS_2O_4 (1 : 1). Cool, fill the flask to the mark and then pour the solution into a clean 3000-cc. flask provided with a rubber stopper. Rinse the measuring flask with exactly 50 cc. of water, which is equivalent to the volume of lead sulfate which is present. Mix the solution thoroughly by shaking, allow the precipitate to settle and filter through a dry filter until 1800 cc. of filtrate has been obtained.

Place exactly 1800 cc. of filtrate (equivalent to a 200-g. charge) in a No. 9 porcelain evaporating dish and evaporate the solution to approximately 100 cc. Transfer the solution to a 600-cc. beaker, neutralize with ammonia, and then add 5 cc. of HCl (sp. gr. 1.19) for every 100 cc. of solution. Warm the solution and pass in a rapid current of hydrogen sulfide until it is saturated. Digest for 30 minutes on the steam bath, add an equal volume of water and again saturate with hydrogen sulfide. Filter and wash with acidulated H_2S water.

Discard the precipitate and evaporate the filtrate in glassware containing no zinc (such as Pyrex) until the volume of the solution is approximately 100 cc.

Neutralize the solution with ammonium hydroxide, add 5 g. of citric acid, and warm until the acid is dissolved. Add small portions of calcium carbonate to the hot citric acid solution until about 1 g. of calcium citrate has separated and then pass in a rapid current of H_2S as the solution is allowed to cool. Allow the solution to stand for from 2 to 4 hours, part of the time on a water bath, until the supernatant liquid is clear.

Collect the precipitate on a filter, wash with a 2-per-cent solution of ammonium thiocyanate and then dissolve the precipitate in hot dilute hydrochloric acid (1 : 3). If the solution has a reddish color (due to iron) the zinc must be reprecipitated as above. If the solution is clear, evaporate it to dryness on the steam bath, take up the residue in 3 cc. of HCl (sp. gr. 1.19) add 20 cc. of water and filter if not perfectly clear.

Transfer the solution (Note 2) to a 50-cc. Nessler jar and dilute to 45 cc. Prepare other Nessler jars containing 3 cc. of HCl (sp. gr. 1.19) definite volumes of standard zinc solution, and diluted to 45 cc. Add 5 cc. of potassium ferrocyanide solution to each jar, mix quickly, and compare the turbidities by viewing longitudinally as the jars are held over a sheet of fine print. Add more of the standard zinc solution from a burette to the jar which approximates the turbidity of the unknown most closely, until the turbidities match each other and calculate the percentage of zinc on the basis of a 200-g. sample or the aliquot portion taken.

NOTES

1. All glassware that contains zinc must be avoided and in umpire work a blank test should be carried along with the test.

2. The whole solution can be used if the lead contains no more than 0.002 per cent of zinc. If more zinc is present it is best to take such an aliquot portion of the solution as will give approximately 4 mg. of zinc and then to add enough HCl to provide 3 cc.

3. For further details concerning the turbidmetric test, consult the "Determination of Small Quantities of Zinc" by Mr. Bodansky, in the *Journal of Industrial and Engineering Chemistry*, Vol. 13, pp. 696–697 (1921).

4. The addition of calcium carbonate with the formation of a precipitate of calcium citrate serves the purpose of giving a clear filtrate, and prevents the loss of colloidal sulfide.

DETERMINATION OF NICKEL AND COBALT

SOLUTIONS REQUIRED

Hydrogen Sulfide Wash Water.—To each 100 cc. of hydrogen sulfide water add 20 cc. neutral ammonium acetate.

METHOD

Render the filtrate just alkaline with ammonia and saturate with H_2S. Heat to boiling and then make just acid with acetic acid, add 20 cc. of neutral ammonium acetate solution, and boil until the sulfides of nickel and cobalt separate out. Filter and wash with warm H_2S wash water. Dry the precipitate and paper in a porcelain crucible and carefully ignite. If there is an appreciable amount of residue after ignition, dissolve by boiling with 10 cc. of aqua regia, wash into a 250-cc. beaker, add 10 cc. of H_2SO_4 (1:1), evaporate until fumes appear, cool, dilute to 200 cc., make alkaline with ammonia, and add 15 cc. of concentrated ammonia. Then electrolyze the solution and weigh the nickel and cobalt as such.

NOTES

If the amount of nickel and cobalt is small it can be weighed as oxide.

If the filtrate from the nickel and cobalt sulfides shows a brown color, it indicates that the precipitation has not been complete. In this case render the solution ammoniacal and repeat the above process.

STANDARD METHODS OF CHEMICAL ANALYSIS OF SPELTER[1]

Serial Designation: B 38 – 21

These methods are issued under the fixed designation B 38; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ADOPTED, 1911; REVISED AND PRINTED AS SEPARATE STANDARD, 1921.

The methods that follow are based on the Report of the Sub-Committee on Methods of Analysis of Non-Ferrous Alloys for the Division of Industrial Chemists and Chemical Engineers of the American Chemical Society, approved by the Supervisory Committee on Standard Methods of Analysis of that Society.[2] These methods were originally proposed by Elliott and Storer[3] and Price[4] whose work has been checked and elaborated by the members of the Committee of the American Chemical Society and of this Society.

The methods are those generally accepted in the United States for standard analysis in all the large laboratories of both producers and consumers of zinc and zinc products.

The Electrolytic and Lead-Acid methods described below are believed to be of equal merit, so far as accuracy is concerned, but where laboratories are equipped for electrolysis the electrolytic method is preferred as a time saver.

DETERMINATION OF LEAD BY THE ELECTROLYTIC METHOD

APPARATUS.

Platinum cylindrical gauze electrodes containing approximately 400 meshes per sq. cm. (50 meshes per linear inch) are recommended

[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee B-2 on Non-Ferrous Metals and Alloys.

[2] *Journal of Industrial and Engineering Chemistry*, Vol. 7, 1915, p. 547.

[3] *Memoirs*, Am. Acad. Arts and Sciences, 8, Part 1, May 20 (1860).

[4] *The Chemical Engineer*, 9 (1909), 4.

for anode and cathode. They should be stiffened by doubling the gauze for about 3 mm. at the top and at the bottom of the cylinders. The anode should be approximately 30 mm. in diameter and 30 mm. in height. The stem should be made from 1.14-mm. or 1.29-mm. wire, flattened and electrically welded the entire width of the gauze; the height over all should be approximately 130 mm., and the gauze should be sand blasted. The cathode should be approximately 12 mm. in diameter by 30 mm. in height, the stem being of the same dimensions and welded in the same way as the anode.

METHOD.

Place 8.643 g. (Note 1) of the sample in a 400-cc. beaker, add sufficient water to cover and then add 30 cc. HNO_3 (sp. gr. 1.42) gradually. When action is complete, boil the solution for 10 minutes, wash off the watch glass, and transfer the solution to a 200-cc. electrolytic beaker, washing out the original 400-cc. beaker. Dilute to 125 cc. and electrolyze (Note 2) with a current of five amperes for 45 minutes. (Note 3.) Test the solution for complete precipitation of lead by washing the watch glasses and sides of the beaker, increasing the depth of the solution about 12 mm. Continue the current for 15 minutes and if the newly-exposed surface is still bright, wash the anode (Note 4) three or four times with distilled water, once with alcohol, and then dry in an oven (Note 5) at 210° C. for 30 minutes, cool in a desiccator and weigh.

The weight of the deposited PbO_2, in milligrams, divided by 100, gives the percentage of lead (Note 6).

NOTES.

1. The empirical factor weight, 8.643 g., is used instead of the theoretical one (8.660 g.) as dried dioxide contains some adherent and included water, not entirely expelled.

2. Before electrolyzing, the beaker should be covered with split watch glasses to prevent loss by spraying.

3. The time required for complete deposition is usually 30 to 45 minutes. For small amounts of lead 30 minutes will be found sufficient.

4. The washing should be done immediately, as the deposit of PbO_2 tends to dissolve.

5. The anode may also be dried on a hot plate, although a drying oven is to be preferred.

6. The PbO_2 deposit can be readily removed by immersing the anode in hot dilute solution of HNO_3 to which oxalic acid has been added, or by covering with dilute HNO_3 and inserting a rod of copper.

DETERMINATION OF LEAD BY THE LEAD ACID METHOD.

SOLUTIONS REQUIRED.

Lead Acid.—Pour 300 cc. of H_2SO_4 (sp. gr. 1.84) into 1800 cc. of distilled water; dissolve 1 g. of lead acetate in 300 cc. of distilled water and add to the acid solution with stirring. Allow to settle for several days and siphon off the clear solution through a thick asbestos pad. (Note 1.)

Nitric Acid.—Mix 1000 cc. of HNO_3 (sp. gr. 1.42) with 1000 cc. of distilled water.

Alcohol.—Mix 1000 cc. of ethyl alcohol (95-per-cent) with 1000 cc. of distilled water.

METHOD.

Place sample (Note 2) of 25, 15, 10, or 5 g. in a 350-cc. beaker and add 300, 180, 120 or 60 cc., respectively, of lead acid. After all but about 1 g. is dissolved, filter on a close filter and wash out the beaker twice with lead acid from a wash bottle. Wash the undissolved matter from the filter into the original beaker with water and dissolve with 10 cc. of HNO_3. Add 40 cc. of lead acid, and evaporate until copious fumes of H_2SO_4 are evolved. When cool, add 35 cc. (Note 3) of water, heat to boiling and add the first filtrate (Note 4), stir well and allow to stand over night (Note 5). Filter on a Gooch crucible, wash with lead acid, then with alcohol-water mixture, and finally with alcohol alone. Set the Gooch crucible inside of a larger porcelain crucible (Note 6) and heat for five minutes at the full heat of a Tirrill burner. Cool and weigh as $PbSO_4$.

NOTES.

1. When lead acid is used, it is unnecessary to consider the solubility of $PbSO_4$, since the solution is always brought back to the same volume as the lead acid used originally, consequently it will retain no $PbSO_4$ from the sample.

2. The amount of sample taken is governed by the grade of spelter:

Grade No. 1, 25 g.	Grade No. 3, 10 g.
Grade No. 2, 15 g.	Grade No. 4, 5 g.
Grade No. 5, 5 g.	

3. The 35 cc. of water added is the quantity of water evaporated from the lead acid.

4. The first filtrate, which contains the greater part of the zinc, may also contain a small amount of $PbSO_4$.

5. It is preferable to allow the solution and precipitate of $PbSO_4$ to stand over night, although this time may be shortened to not less than five hours.

6. The Gooch crucible is heated inside of a porcelain crucible to avoid reduction of the $PbSO_4$ by flame gases and mechanical disintegration of the asbestos mat.

DETERMINATION OF IRON.

SOLUTIONS REQUIRED.

Dilute Ammonia Water.—Mix 100 cc. of NH_4OH (sp. gr. 0.90) with 1000 cc. of distilled water.

Sulfuric Acid (1 : 4).—Mix 250 cc. of H_2SO_4 (sp. gr. 1.84) with 1000 cc. of distilled water

Sulfuric Acid (1 : 1).—Mix 500 cc. of H_2SO_4 (sp. gr. 1.84) with 500 cc. of distilled water.

Dilute Sulfuric Acid for Reductor.—Mix 50 cc. of H_2SO_4 (sp. gr. 1.84) with 1000 cc. of distilled water. This solution is used boiling hot.

Potassium Permanganate.—Dissolve 0.2 g. of $KMnO_4$, C.P., in 1000 cc. of distilled water. Allow to stand for several days in a glass-stoppered bottle in a dark closet, and then filter through prepared asbestos. Standardize against 0.020-g. portions of pure sodium oxalate, dissolved in 200 cc. of the dilute H_2SO_4 for reductor. Each cubic centimeter of $KMnO_4$ is equivalent to approximately 0.00033 g. of iron.

METHOD.

Place 25 g. of the sample in a tall 700-cc. beaker and dissolve cautiously with 125 cc. of HNO_3 (sp. gr. 1.42). Boil, dilute to about 300 cc., add 10 g. of NH_4Cl and then ammonia water (sp. gr. 0.90) until the precipitated $Zn(OH)_2$ has redissolved. Boil, let settle and filter on an 11-cm. filter paper (Note 1). Wash with dilute ammonia water and then with hot water until free from chlorides. Dissolve precipitate from the paper with hot H_2SO_4 (1 : 4), add 40 cc. of H_2SO_4 (1 : 1), cool, and pass through a Jones reductor (Note 2). Wash out the reductor first with 150 cc. of dilute H_2SO_4 for reductor and then with 100 cc. of distilled water and titrate with standard $KMnO_4$ solution (Note 3).

NOTES.

1. A filter paper which will retain $Fe(OH)_3$ and filter rapidly should be used. Whenever the amount of iron is at all large or when great accuracy is demanded, a second precipitation of $Fe(OH)_3$ should be made by dissolving the precipitate on the paper in hot dilute HCl, adding ammonia water and filtering, in order to remove all traces of nitrates.

2. The reductor should be clean, preferably washed out with 150 cc. of dilute H_2SO_4 and 100 cc. of water first. If, before passing through the reductor, a large amount of $PbSO_4$ is present, it is well to filter it off so as to prevent it from clogging the reductor. A small quantity of liquid should always be left in the reductor funnel, and air should never be allowed to enter the body of the reductor. For description and further details of use of reductor, see "The Chemical Analysis of Iron," by A. A. Blair, or "Quantitative Chemical Analysis," by H. P. Talbot.

3. A blank determination should be made on corresponding amounts of acid and water passed through the reductor and the results should be corrected accordingly. About 0.5 cc. of the $KMnO_4$ solution will be required to give a permanent coloration to the solution.

DETERMINATION OF CADMIUM GRAVIMETRICALLY.

SOLUTIONS REQUIRED.

Sulfuric Acid (1 : 1).—Mix 500 cc. of H_2SO_4 (sp. gr 1.84) with 500 cc. of distilled water.

Sulfuric Acid (1 : 5).—Mix 200 cc. of H_2SO_4 (sp. gr. 1.84) with 1000 cc. of distilled water.

Hydrochloric Acid (1 : 3).—Mix 250 cc. of HCl (sp. gr. 1.19) with 750 cc. of distilled water.

METHOD.

Place 25 g. of drillings in a tall 500-cc. beaker; add 250 cc. of water and 55 cc. of HCl (sp. gr. 1.19) and stir. When the action has almost ceased add more acid with stirring, using about 2 cc. at a time and allowing to stand after each addition, until finally all but about 2 g. of the zinc has been dissolved. (Note 1.) Filter, first transferring one of the undissolved pieces of zinc to the filter, and wash twice with water. Discard the filtrate. Wash the undissolved matter on the filter paper into the 500-cc. beaker, cover and dissolve in 10 cc. of water and 10 cc. of HNO_3 (sp. gr. 1.42). Transfer to a casserole, add 20 cc. of H_2SO_4 (1 : 1) and evaporate until fumes appear. Take up with 100 cc. of water, boil, cool, and let settle over night. (Note 2.) Filter off the $PbSO_4$ on paper, wash twice with water, retain the filtrate but discard the paper and precipitate. Dilute the filtrate to 400 cc., add about 10 g. of NH_4Cl, and pass H_2S gas through for 1 hour (Note 3). Allow to stand until the precipitate has settled, and filter off the impure CdS (Note 4) on a loose-bottom Gooch crucible. Remove the precipitate by punching out the bottom into a tall 200-cc. beaker, wiping off the sides of the crucible with a little asbestos pulp. Add 60 cc. of H_2SO_4 (1 : 5) and boil for 30 minutes (Note 5). Filter, wash, and dilute to 300 cc., add about 5 g. of NH_4Cl and precipitate with H_2S gas as before (Note 6). Repeat, making a third precipitation if the amount of cadmium present is large (Note 7). After the final precipitation, let settle, filter and transfer to a weighed platinum dish, cover, and dissolve in HCl (1 : 3). Dissolve the precipitate remaining on the paper in hot HCl (1 : 3) and add also to the solution in the

platinum dish (Note 8). Add 10 cc. of H_2SO_4 (1 : 1) and evaporate the solution until copious fumes are evolved (Note 9). Remove the excess of H_2SO_4 by heating the dish cautiously, and finally heat to between 500 and 600° C. Cool and weigh as $CdSO_4$.

NOTES.

1. The addition of HCl will dissolve the zinc and a small amount of the cadmium. adding the acid in small quantities, *i.e.*, keeping the acidity low, and also keeping the solution cold, the amount of cadmium dissolved will be small. Since it requires some time to completely reprecipitate any cadmium dissolved, it is desirable for the solution to stand over night following the addition of the 55 cc. of HCl at the start. For the same reason the solution should be allowed to stand after the last addition of acid, and care be taken that the stated amount of spelter remain in the undissolved residue. If the solution is heated, or if time is not allowed for the action of the acid to cease completely, small amounts of cadmium may pass into the solution and be lost.

Equally satisfactory, or in some cases more satisfactory results are obtained by using H_2SO_4 to dissolve the major portion of the zinc. The rate of solution is slower and the tendency for cadmium to pass into solution less. The quantity of acid required can be calculated, measured out at the beginning and small quantities added from time to time as the action becomes slow.

2. It is desirable to allow it to settle over night to precipitate all the $PbSO_4$ from the solution and to give good conditions for filtering.

3. It is occasionally necessary to add a drop or two of ammonia water to the solution to start the precipitation of CdS.

4. All the cadmium will be precipitated as sulfide together with some ZnS. The major portion of the zinc will remain in solution.

5. In case of high cadmium content, more acid may be required.

6. The second precipitation should give practically pure CdS.

7. A third precipitation will remove any uncertainty as to the completeness of the separation of cadmium from zinc.

8. A crucible may also be used if the volumes are kept small or evaporated before transferring to the crucible.

9. On evaporating to fumes, darkening of the solution may occur from filter paper shreds. This may be destroyed by diluting slightly with water and adding 5 cc. HNO_3 (sp. gr. 1.42) and again evaporating to fumes.

DETERMINATION OF CADMIUM BY THE ELECTROLYTIC METHOD.

SOLUTIONS REQUIRED.

Potassium Hydroxide. (Note 1).—Dissolve 20 g. of KOH, c.p., in 200 cc. of distilled water.

Potassium Cyanide (Note 2).—Dissolve 20 g. of KCN, c.p., in 200 cc. of distilled water.

APPARATUS.

See "Determination of Lead by the Electrolytic Method."[1] The anode, as used in the lead determination, is here used as the cathode, and *vice versa*.

METHOD.

See "Determination of Cadmium Gravimetrically."[2]

Dissolve the final precipitate of CdS in hot HCl (1 : 3), boil to remove H_2S, adding a few drops of HNO_3 (sp. gr. 1.42) near the end, and filter off the separated sulfur. Transfer the solution to a 200-cc. electrolytic beaker, add a drop or two of phenolphthalein and then KOH solution until a permanent red color is obtained. Add KCN solution with constant stirring until the precipitate of $Cd(OH)_2$ is completely dissolved (Note 3). Dilute to 150 cc. and electrolyze with a current of five amperes for two hours (Note 4). Test for completeness of deposition by washing the watch glasses and sides of the beaker to increase the depth of the solution. Continue electrolysis for twenty minutes and if the newly-exposed surface of the cathode is still bright, remove the beaker with electrolyte and wash the electrodes three times with distilled water and twice with ethyl alcohol (95-per-cent). Dry the cathode at 100° C., cool and weigh. The increase is metallic cadmium.

NOTES.

1. Pure NaOH may be used in place of KOH.
2. Pure NaCN may be used in place of KCN.
3. Avoid using an excess of KCN.
4. The test for completeness of deposition may be made after one hour when the quantity present is not large.

[1] See p. 679. [2] See p. 683.

STANDARD METHODS OF CHEMICAL ANALYSIS OF NICKEL[1]

Serial Designation: B 41 – 23

These methods are issued under the fixed designation B 41; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1921; ADOPTED, 1923.

DETERMINATION OF IRON.

(*a*) *By the Cuprous Chloride Method.*

SOLUTIONS REQUIRED.

Cuprous Chloride Solution.—Place into a 2-liter heavy glass bottle, 400 g. NaCl, 100 cc. HCl and 20 g. Cu_2Cl_2. Add 2 liters of warm water; shake well; place into the solution a few copper rods and let stand over night in a cool place. After shaking, the solution is ready for use.

One cubic centimeter of Cu_2Cl_2 should reduce 0.003 g. to 0.005 g. of iron.

METHOD.

Dissolve 10 g. of nickel drillings in 100 cc. dilute HNO_3 (1:2) in a 600-cc. covered beaker, add 1 or 2 g. $KClO_3$, boil for 30 minutes, add about 100 cc. cold water, make alkaline with NH_4OH and add about 50 cc. in excess. Boil a few minutes, filter, wash the precipitate with hot water two or three times.

Re-dissolve the precipitate in hot HCl (1 : 3). After the precipitate is dissolved make the solution alkaline with NH_4OH, boil a few minutes, filter and wash with hot water. Dissolve the $Fe(OH)_3$ in 30 cc. hot HCl (1 : 3) in a 24-oz. flask, cool, add about 300 cc. cold water and titrate with a standard Cu_2Cl_2 solution using two drops of a saturated solution of KCNS as an inside indicator. Titrate to faint opalescence.

[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee B-2 on Non-Ferrous Metals and Alloys.

NOTES.

The Cu_2Cl_2 solution should be standardized each time before using, with 10 cc. of standard ferric chloride, to which 5 cc. of HCl is added, diluted to 300 cc. with cold water and titrated to faint opalescence. The ferric chloride is made by dissolving 5 g. of standard iron wire in 150 cc. of HCl (1 : 1); then 5 g. $KClO_3$ is added to oxidize the iron. Add 1 liter of water and boil until all the free chlorine is driven off. Boil about eight hours, keeping the volume of the solution about one liter, then cool and make the solution up to two liters.

The above method is used for determining iron in material with less than 5 per cent iron, using a 1-g. sample, and when less than 0.5 per cent using a 10-g. sample.

The solution gains in Cu_2Cl_2, and should now and then be diluted with a solution containing 20 per cent of NaCl and 5 per cent of HCl. If the solution should fall off in Cu_2Cl_2, add about 5 g. Cu_2Cl_2.

(b) By Potassium Permanganate Method.

SOLUTIONS REQUIRED.

Standard Potassium Permanganate Solution.—Standardized by means of sodium oxalate (as furnished by the Bureau of Standards).

METHOD.

Dissolve the $Fe(OH)_3$ in dilute H_2SO_4 and reduce the iron with Zn, and then titrate with $KMnO_4$.

NOTE.

This method is just as accurate as the Cuprous Chloride Method providing 5 g. of the drillings are taken.

DETERMINATION OF CARBON BY THE DIRECT-COMBUSTION METHOD

APPARATUS.

Purifying Train.—The purifying train should consist of a 5-in. "U" tube filled with glass beads and moistened with H_2CrO_4 solution, with a loose plug of glass wool in the forward end. This serves to oxidize any SO_2 and to absorb the SO_3 formed from the sulfur in the nickel drillings during combustion. This tube should be washed out daily and fresh glass wool inserted.

Material for Lining Boats.—The boat may be filled with ignited alumina. Alundum, "RR Alundum, alkali-free, specially prepared for carbon determination" is also recommended.

Catalyzers.—The forward end of the platinum combustion tube should contain a plug of loosely wound platinum gauze, $5\frac{1}{2}$ in. long, completely filling the bore of the tube and a similar roll 2 in. long, fitted with a loop, pushed in after the boat.

Combustion Apparatus.—The apparatus may be heated by gas or electricity and combustion tubes may be of platinum, quartz, or porcelain glazed on one or both sides.

Boats or Other Containers of Samples being Burned.—These may be of alundum, but porcelain, quartz, clay and platinum are also recommended.

Absorption Train.—It is recommended that the absorption train consist of a Geissler potash bulb with a calcium chloride tube attached.

REAGENTS.

Oxygen.—Oxygen of not less than 97-per-cent purity is recommended. Endeavor should be made to obtain oxygen which gives no blank since the correction for or elimination of this is troublesome and uncertain. For the most accurate work the blank should be completely eliminated by the use of a catalyzer before the furnace with a CO_2 absorbent interposed between the furnace and the catalyzer.

Potassium Hydroxide Solution.—A KOH solution (sp. gr. 1.27) should be used as the absorbent for CO_2 but the use of "Ascarite" is also recommended.

FACTORS INFLUENCING RAPID COMBUSTION.

Size of Particles of Sample.—The finer the chips the better, except with samples which burn too vigorously. Particles too coarse to pass a 20-mesh sieve are not recommended, nor long, curly drillings which will not pack closely. Oil, dust and other foreign matter should be carefully excluded.

Manner of Distributing Sample in Boat.—The method of distributing the sample in the boat is of considerable importance. With all samples, close packing in a small space is conducive to rapid combustion. In the case of samples which burn too vigorously, a satisfactory regulation may sometimes be attained by spreading the sample loosely over the lining in the boat.

Rate of Admitting Oxygen.—The valve controlling the supply of oxygen must be regulated so as to keep a slow current of gas passing through the absorption apparatus at all times and not to exceed three bubbles in a second.

METHOD.

After having properly set up and tested the apparatus, fill the alundum boat with ignited alumina and make a "V"-shaped depression in the middle with a spatula, pressing the material against the sides of the boat. Ignite the boat and its contents strongly to expel any CO_2 present and burn off any carbonaceous matter that the alumina may contain. Weigh out 3 g. of nickel drillings which have

been broken down so as to pass through a No. 20 sieve and transfer it to the boat. Introduce the boat into the combustion apparatus. Burn the carbon by starting a slow current of oxygen and lighting one of the burners at the forward end of the tube, and as soon as the tube is red hot increase the heat slowly by lighting the other burners. Nickel is burned at a temperature of 1200° C. for 20 minutes.

DETERMINATION OF SULFUR.

SOLUTIONS REQUIRED.

Barium Chloride.—A 20-per-cent solution should be used.

METHOD.

Weigh duplicate 10-g. samples of drillings, place each into an 800-cc. casserole and treat as follows:

Add 3 g. of $KClO_3$, cover and then add 200 cc. strong HNO_3. Place on steam bath until action has ceased and then evaporate to dryness on the hot plate. Cool and then add 50 cc. HCl and again evaporate to dryness. Repeat this operation. Take up with 150 cc. water, add 8 cc. HCl, heat to boiling, filter and wash, taking care that the filtrate and washings do not exceed 300 cc. in volume. Heat the filtrate to boiling, add 25 cc. of 20-per-cent $BaCl_2$ solution and allow it to stand in a warm place over night. Filter through a small double ashless filter paper and wash with very dilute HCl, and finally with hot water. Ignite in a small platinum crucible and then heat to bright redness for twenty minutes. Cool and weigh the $BaSO_4$.

NOTES.

$BaSO_4 \times 0.1373 =$ sulfur.

Run a blank analysis, that is, take an 800-cc. casserole, add to it all the reagents and subject the contents to the same operations as the samples of drillings at the same time. Deduct any $BaSO_4$ obtained from the result of the actual assay. If this blank amounts to 0.0040 g., the reagents are unfit for the above analysis and the determinations should be repeated with other reagents.

DETERMINATION OF NICKEL AND COBALT.

(*a*) *By Electrolysis.*

APPARATUS.

Electrodes.—It is recommended that the cathode consist of a platinum cylinder 50 mm. by 38 mm. in diameter; with stem diameter 1½ mm. and height 127 mm.

The anode should consist of a spiral of iron wire 1½ mm. in diameter.

METHOD.

Dissolve 2 g. of nickel drillings in 30 cc. of HNO_3 (1 : 1) in a 400-cc. covered beaker, add 30 cc. HS_2O_4 (1 : 1) and evaporate until fumes of H_2SO_4 are given off copiously. Dilute with 250 cc. of water. Boil, cool and precipitate the copper with H_2S. Filter into a 600-cc. plain beaker, wash the precipitate with hot water, boil the filtrate gently until about one-third of the volume is evaporated, to remove the H_2S. Add 10 cc. H_2O_2 to oxidize the iron, cool, add 100 cc. NH_4OH water, then plate out the nickel and cobalt on a weighed platinum cylinder using a current of 0.6 ampere. It takes about 14 hours to plate out the nickel.

Make a replate on solution to recover the small amount of nickel which is left.

To make the replate, remove the beaker, add H_2SO_4 to the solution until acid, then add about 5 cc. in excess, cool, add 60 cc. NH_4OH water, then plate out nickel with a current of 1 ampere for two hours. Wash the cathode with water and alcohol, heat over an alcohol lamp and when cool weigh. Increased weight equals nickel and cobalt.

The cathode on which the nickel and cobalt have been plated is placed in a 125 cc. plain beaker. Dissolve the nickel and cobalt in dilute HNO_3 and remove the cathode. Evaporate the solution to a syrupy consistency, cool, add 25 cc. water, boil, neutralize with K_2CO_3 solution, make slightly acid with 50-per-cent acetic acid, then add 10 cc. of 50-per-cent acetic acid and make the volume up to 50 cc. In another beaker, dissolve 25 g. KNO_2 in 50 cc. water, and make acid with acetic acid. Add the nitrite solution to the solution containing the nickel and cobalt, while boiling. Let stand in a warm place over night. Filter and wash the precipitate with a 5-per-cent KNO_2 solution made acid with acetic acid. The precipitate is transferred to a 300-cc. beaker by washing with hot water and dilute H_2SO_4, add 20 cc. H_2SO_4 (1 : 1) and evaporate until fumes of sulfuric acid are given off copiously. Dilute with 150 cc. water. Boil, cool and add 100 cc. NH_4OH water. Plate over night using a current of 0.5 ampere. Weigh as cobalt.

Subtract the percentage of cobalt found from the percentage of cobalt and nickel. The difference is nickel.

NOTE.

When manganese is present, a solution containing 30 cc. of water and 2 g. of Na_2O_2 is added to the alkaline solution just before plating out the nickel and cobalt and also just before making the replate on the solution.

STANDARD METHODS OF CHEMICAL ANALYSIS OF ALLOYS OF LEAD, TIN, ANTIMONY AND COPPER[1]

Serial Designation: B 18 – 21

These methods are issued under the fixed designation B 18; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1917; ADOPTED IN AMENDED FORM, 1921.

These methods were approved November 13, 1922, as "Tentative American Standard" by the American Engineering Standards Committee.

These methods apply particularly to white metal bearing alloys (known commercially as "Babbitt Metal") and to similar lead and tin base alloys.

Two sets of methods are here given. The first method is somewhat slow but is recommended as giving the more accurate results where the analysis of these alloys is of comparatively infrequent occurrence. The second method is rapid and is suitable for control work, giving good results after the analyst has become familiar with it.

GENERAL METHOD[2]

A DETERMINATION OF LEAD, COPPER, ANTIMONY AND TIN.

DETERMINATION OF LEAD.

SOLUTIONS REQUIRED.

Mixed Acid.—Dissolve 20 g. of KCl in 500 cc. of water, add 400 cc. of HCl (sp. gr. 1.20), mix and add 100 cc. of HNO_3 (sp. gr. 1.42).

Alcohol-Hydrochloric Acid Mixture.—Mix 400 cc. of 95-per-cent ethyl alcohol and 100 cc. of HCl (sp. gr. 1.20).

Acid Ammonium Acetate.—To 500 cc. of NH_4OH (sp. gr. 0.90), add 500 cc. of water and then acetic acid (80-per-cent), until slightly acid to litmus.

[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee B-2 on Non-Ferrous Metals and Alloys.

[2] G. W. Thompson's method. See *Journal*, Soc. Chem. Ind., Vol. 15, p. 179.

METHOD.

Dissolve 1 g. of the finely divided alloy by boiling in 70 to 100 cc. of "mixed acid" solution in a covered beaker. Add more "mixed acid" if a complete solution of the alloy is difficult to obtain, and continue boiling until evaporated to about 50 cc. Add 5 cc. of HCl (sp. gr. 1.20), cool in ice water until the bulk of $PbCl_2$ has crystallized out, then add slowly, with constant stirring, 50 cc. of alcohol (95-per-cent), continue stirring for a few minutes and cool in ice water for 10 minutes. Add 50 cc. more alcohol from a pipette, allow to stand in ice water for 20 minutes and filter through 9-cm. paper into an 800-cc. beaker. Wash by decantation three times with alcohol-hydrochloric acid mixture and finally wash the paper twice with the same mixture. Wash the $PbCl_2$ from the paper back into the beaker; wash paper several times with hot water, catching washings in beaker with the bulk of the chloride. Finally wash paper with hot acid ammonium acetate solution. Heat until all $PbCl_2$ is dissolved. Add 15 cc. of saturated solution of $K_2Cr_2O_7$; heat until precipitate is of good orange color; filter on weighed Gooch crucible; wash with water, alcohol and ether; dry at 110° C. and weigh. Calculate percentage of lead by the empirical factor 63.75.

NOTES

1. With proper manipulation, the $PbCl_2$ precipitate should contain consistently all but 0.003 g. of lead.

2. During the heating of the acid ammonium acetate to dissolve the $PbCl_2$, the solution should remain perfectly clear, any turbidity indicating the presence of tin or antimony, as even 1 mg. of tin or antimony will cause a slight but distinct turbidity.

DETERMINATION OF COPPER AND ANTIMONY.

SOLUTIONS REQUIRED.

Potassium Hydroxide.—Dissolve 100 g. of KOH in 500 cc. of water.

Potassium Cyanide.—Dissolve 3.5 g. of KCN in 1800 cc. of water and standardize against copper of known purity.

Sodium Thiosulfate.—Dissolve 24.8 g. of $Na_2S_2O_3 \cdot 5H_2O$ in 1000 cc. of water, and allow to stand for 24 hours. Standardize against Antimony Metal c. p., using same quantity of reagents and same procedure as under (*c*) Determination of Antimony.

METHOD.

See "Determination of Lead."[1]

Evaporate the filtrate from $PbCl_2$ filtration by boiling in the loosely covered 800-cc. beaker, and finally take to dryness on a water bath. Add 10 cc. of KOH solution and after a few minutes add 20 cc. of 3-per-cent H_2O_2. Add more KOH, if solution is acid, until an alkaline reaction is shown by litmus paper. Heat on the water bath for 20 minutes, add 10 g. of ammonium oxalate, 10 g. of oxalic acid, and 200 cc. of water and heat to boiling. Pass in H_2S for 45 minutes with solution near boiling; filter at once; and wash precipitate with hot dilute solution of oxalic acid saturated with H_2S, catching washings with filtrate.

Wash the precipitate of copper and antimony sulfides from the filter paper back into the beaker with the least amount of water possible; treat with 10 cc. of KOH solution; heat on water bath until the undissolved matter is distinctly black, filter through same paper into a 300-cc. Erlenmeyer flask. Wash the precipitate with hot water containing a small amount of K_2S.

(*a*) *Determination of Copper by Potassium Cyanide Titration.*

Dry and ignite the precipitate with paper in a small casserole, dissolve in nitric acid (sp. gr. 1.42), boil to expel nitrous fumes, neutralize with Na_2CO_3, add a few drops of NH_4OH and titrate with standard KCN solution.

(*b*) *Determination of Copper by Electrolytic Method.*

See "Determination of Copper by Potassium Cyanide Titration," above.

Dry and ignite the sulfide precipitate in a small casserole, dissolve in 10 cc. of HNO_3 (sp. gr. 1.42), boil until oxides of nitrogen are expelled and add 50 cc. of distilled water. Transfer to a tall 200-cc. beaker, wash out casserole, add 5 cc. of H_2SO_4 (sp. gr. 1.84) and determine copper by electrolysis. See the determination of copper by the electrolytic method in the Standard Methods of Chemical Analysis of Manganese Bronze (Serial Designation: B 27) of the American Society for Testing Materials.[2]

NOTES.

1. On filter after heating with KOH solution, the copper remains as sulfide with a small amount of lead sulfide which failed to be precipitated as

[1] See p. 691. [2] See p. 700.

chloride. If it is desired to determine this lead, it can be done by separation from the copper by ordinary methods.

2. If the amount of antimony and copper is small (less than 10 mg.) the lead which failed to be precipitated as chloride may also fail to come down as sulfide on passing H_2S through the oxalic solution. It will remain in the filtrate from the sulfides and be deposited electrolytically with the tin on the cathode. This can be prevented by adding an oxalic acid solution of a pure antimony salt containing about 100 mg. of antimony just before passing H_2S. In this case antimony must be determined on a separate portion.

3. If the amount of copper present is from 8 to 10 mg. or more, it should be determined by the electrolytic method. In this case, the small amount of lead precipitated as sulfide with the copper is deposited on the anode as PbO_2 and may be weighed, calculated to lead by factor 86.43 and added to that obtained under "Determinations of Lead".

(*c*) *Determination of Antimony.*

See "Determination of Copper by Potassium Cyanide Titration," above.

Add 50 cc. of HCl (sp. gr. 1.20) to the KOH solution of antimony sulfide, and boil down to small volume until all arsenic has been expelled as arsenious chloride.

Add 25 cc. of HCl (sp. gr. 1.20) and 1 g. of $KClO_3$ and boil until colorless. Filter into a 300-cc. Erlenmeyer flask, through glass wool if sulfur has separated, wash out original flask with HCl (sp. gr. 1.20), cool, add 1 g. of KI, 1 cc. of CS_2, and titrate with standard thiosulfate solution.

DETERMINATION OF TIN.

APPARATUS FOR ELECTROLYSIS.

Electrodes.—Cylindrical cathodes of platinum wire gauze—2 by $1\frac{3}{8}$ in. diameter.

Platinum wire spiral anodes.

METHOD.

See "Determination of Copper and Antimony."[1]

Concentrate the filtrate and washings from the precipitated sulfides, if necessary, to a volume of 200 cc. and add 5 g. more of oxalic acid in case the amount of tin is over 0.5 g. Electrolyze until the solution reacts alkaline, using a current of about 0.5 amperes. Remove the cylinder; wash twice with distilled water and once with 95-per-cent ethyl alcohol; dry at 110° C. and weigh.

[1] See p. 692.

NOTE.

If the electrolysis is carried out over night it will usually be found by morning that the solution has become alkaline and it may be taken for granted that the tin has all been precipitated on the cathode. The best results are obtained by regulating the current, or the time, so as to render the solution alkaline only a very short time before the cathode is to be removed. The cathode should be placed close to the bottom of the beaker to insure proper agitation of the electrolyte.

B. DETERMINATION OF ARSENIC.

SOLUTIONS REQUIRED.

Ferric Chloride.—Solution of specific gravity 1.43.

Ammonium Carbonate.—Dissolve 75 g. in 500 cc. of water.

METHOD.

Weigh 1 g. of sample into a 250-cc. distillation flask and add 10 cc. of $FeCl_3$ solution, 60 cc. of HCl (sp. gr. 1.20) 20 cc. of water and 5 g. of KCl. Connect the flask with a condenser, heat slowly until solution is complete and boil down to as small a volume as possible, catching distillate in a tall 400-cc. beaker. Cool flask, add 50 cc. HCl (sp. gr. 1.20) and redistill as before, catching distillate in same beaker. Cool distillate and pass H_2S through for one hour, allow to settle and filter the arsenious sulfide on a Gooch crucible. Wash twice with HCl (1 : 4), four times with cold water, three times with alcohol and four times with CS_2. Dry at 110° C. for 10 minutes, and weigh after cooling. Dissolve the arsenious sulfide with $(NH_4)_2\ CO_3$ solution, wash thoroughly with water, dry for 30 minutes at 110° C. and reweigh after cooling. The difference in weights multiplied by 0.60911 gives the percentage of arsenic.

RAPID METHOD FOR CONTROL WORK.[1]

A. DETERMINATION OF LEAD AND COPPER.

SOLUTIONS REQUIRED.

"*Lead Acid.*"—Mix 300 cc. of H_2SO_4 (sp. gr. 1.84) and 1800 cc. of distilled water. Dissolve 1 g. of lead acetate c. p.

[1] See "The Analysis of Alloys of Lead, Tin, Antimony and Copper," by D. J. Demorest, *Journal, Ind. and Eng. Chem.*, Vol. V, p. 842; "Rapid Analysis of Alloys for Tin, Antimony, and Arsenic," by F. A. Stief, *Journal, Ind. and Eng. Chem.*, Vol. VII, p. 211; and "Technical Analysis of Brass," 1917. Price and Meade, p. 182.

in 300 cc. of distilled water and add this to the hot solution, stirring meanwhile. Let stand at least 24 hours and siphon through a thick asbestos filter.

Dilute Alcohol for Washing.—Mix equal parts of denatured alcohol and distilled water.

METHOD.

(*a*) *Determination of Lead.*

In a covered 300-cc. Erlenmeyer flask dissolve 1 g. of the alloy in 20 cc. of H_2SO_4 (sp. gr. 1.84); heat the solution nearly to boiling until the metal is completely decomposed and the $PbSO_4$ is white (this may take 30 minutes or more) and finally boil for several minutes. Allow to cool, but not below 60° C., and then add slowly 50 cc. of water while the solution is agitated. Heat to boiling for several minutes in order to insure complete solution of antimony sulfate. Allow the $PbSO_4$ to settle out until the solution is clear, not letting the temperature fall below 60° C. If the liquid does not clear quickly it must be heated longer. When clear, pour the solution through a weighed porcelain Gooch crucible with asbestos mat, decanting the solution as completely as possible without allowing more than a very small amount of $PbSO_4$ to go over into the crucible. Now add 10 cc. more of H_2SO_4 (sp. gr. 1.84) to the $PbSO_4$ in the original flask, and boil for several minutes. Cool, add slowly 30 cc. of water, and again heat to boiling for a few minutes; allow the solution to cool to about 60° C. and completely transfer the $PbSO_4$ to the Gooch crucible. Wash with lead acid, retaining the filtrate and these washings for the copper determination. Remove the beaker containing these solutions and wash out the lead acid with dilute alcohol; set the Gooch crucible inside a porcelain crucible; dry and ignite for five minutes at the full heat of a Tirrill burner; cool and weigh as $PbSO_4$, which contains 68.29 per cent lead.

(*b*) *Determination of Copper.*

To the filtrate from the $PbSO_4$, which contains the copper and which has been transferred to an Erlenmeyer flask, add NH_4OH (sp. gr. 0.90) until the solution is slightly alkaline; then add 2 cc. of H_2SO_4 (sp. gr. 1.84); heat nearly to boiling; add 2 g. of Na_2SO_3 and when this is entirely dissolved add 1 g. of KCNS dissolved in 10 cc. of water. Shake well and allow the precipitated CuCNS to settle for one hour while the solution is kept hot. Filter on a close filter paper, wash with cold water

and ignite paper and precipitate in a porcelain crucible. Proceed by one of the two following methods:

(1) Dissolve in HNO_3 (sp. gr. 1.42), add 5 cc. H_2SO_4 (sp. gr. 1.84); evaporate until fumes of H_2SO_4 are evolved. Dilute to about 100 cc. with distilled water. Add 1.5 cc. of HNO_3 (sp. gr. 1.42) and determine copper by electrolysis. See the "Determination of Copper by the Electrolytic Method," Standard Methods of Chemical Analysis of Manganese Bronze (Serial Designation: B 27) of the American Society for Testing Materials.[1]

(2) Dissolving the ignited precipitate in HNO_3 (sp. gr. 1.42), as in (1); boil to expel nitrous fumes, neutralize with Na_2CO_3 and determine volumetrically with cyanide as in *A* of "General Method."[2]

NOTE.

If the amount of copper is very small it may escape detection by this method, in which case it should be determined as in *A* of "General Method."

B. DETERMINATION OF ARSENIC, ANTIMONY AND TIN.

APPARATUS.

Arsenic Still.—A condenser is made from glass tubing in the form of a letter *S*, about 18 in. long and $\frac{1}{2}$ in. in inside diameter, tapering to about $\frac{1}{4}$ in. at the upper end and to about $\frac{1}{8}$ in. at the lower end. One curve is nearly filled with water, and is submerged in cold water in a 500-cc. beaker. The lower end dips into about 75 cc. of water in a 300-cc. beaker and the upper end is connected by a delivery tube with a 300-cc. Florence flask, closed with a rubber stopper which is fitted with a delivery tube and with a thermometer reaching to about 1 in. above the surface of the liquid in the flask.

SOLUTIONS REQUIRED.

Iodine.—Dissolve 10.7 g. of iodine in 50 cc. of distilled water which contains 20 g. of KI in solution and dilute to 1000 cc. with distilled water. Standardize against pure tin having exactly the same conditions for titration as are specified for the analysis of the alloy. Each cubic centimeter is equivalent to approximately 0.00500 g. of tin or 0.00315 g. of arsenic.

Potassium Permanganate.—Dissolve 2.7 g. of $KMnO_4$ in distilled water, filter through asbestos, and dilute to 1000 cc

[1] See p. 700.
[2] See p. 692.

with distilled water. Standardize against pure antimony having exactly the same conditions for titration as are specified for the analysis of the alloy. Each cubic centimeter is equivalent to approximately 0.00500 g. of antimony or 0.00465 g. of iron.

Ferrous Ammonium Sulfate.—Dissolve 12.4 g. of ferrous ammonium sulfate crystals in 950 cc. of distilled water and add 50 cc. of H_2SO_4 (sp. gr. 1.84).

Starch.—To 1000 cc. of boiling water, add a cold suspension of 6 g. of starch in 100 cc. of distilled water; cool, add a few drops of chloroform and mix thoroughly.

METHOD.

(*a*) *Determination of Arsenic.*

In a 300-cc. Florence flask, dissolve 0.5 g. of the alloy in exactly 8 cc. of H_2SO_4 (sp. gr. 1.84). The metal must be finely divided, preferably in the form of thin foil-like shavings, although sawings or very fine drillings may be used. Heat the solution to boiling; cool, add about 5 cc. of water and a bulk of about 0.5 cc. of clean granulated pumice stone and boil the covered solution very gently for about five minutes, or until the strong odor of SO_2 can no longer be detected. Finally, being careful to have 5 cc. of water present, cool the solution to about 18° C. and cautiously add 20 cc. of HCl (sp. gr. 1.20). Insert in the flask a rubber stopper fitted with a thermometer and delivery tube and connect the delivery tube with the "*S*" condenser. Heat the solution to gentle boiling for from 10 to 15 minutes, keeping the vapor temperature at 107° C. for at least 5 minutes. Wash out the condenser into a 300-cc. beaker and add an excess of about 2 g. of $NaHCO_3$. Bring the volume of the solution to about 200 cc.; warm to about 27° C. and titrate with standard iodine solution and starch to the appearance of a deep blue color.

NOTE.

A blank determination should be made on corresponding amounts of reagents treated as above, and the results should be corrected accordingly.

(*b*) *Determination of Antimony.*

Cool the solution which remains in the flask after the arsenic distillation; add about 130 cc. of cold, recently-boiled distilled water, to which has been added about 3 cc. of HCl (sp. gr. 1.20) and titrate with standard $KMnO_4$ solution to the appearance of a decided permanent pink color. From a burette add an excess

of standard ferrous ammonium sulfate solution until the pink color is discharged and then titrate with standard $KMnO_4$ solution to the reappearance of a pink color.

(*c*) *Determination of Tin.*

If the sample does not contain 14 per cent (or 0.07 g.) of antimony, add enough dissolved $SbCl_3$ to the solution to bring the contents of antimony up to about 0.07 g. for the purpose of insuring perfect reduction of the tin and uniform conditions for the titration. Then add exactly 6 cc. of H_2SO_4 (sp. gr. 1.84) and 60 cc. of HCl (sp. gr. 1.20) and add about 6 in. of clean, soft No. 14 pure iron wire cut into 2-in. lengths and cleaned with dilute HCl just before using. Boil gently for 30 minutes, add about 6 in. more wire and boil 30 minutes longer. Remove from heat, close flask loosely with a rubber stopper and allow about two minutes for all air to be expelled by hydrogen and acid vapors. Close flask tightly and quickly place it in cold water, cooling the solution to about 20° C. Transfer the solution quickly to a 500-cc. beaker (leaving the iron wires in the flask) and rinse flask and contents with 150 cc. of cold, recently-boiled distilled water. Add rinsings to main solution in the beaker, bring final volume to about 300 to 350 cc. and titrate quickly with standard iodine solution and starch to the appearance of a strong blue color.

NOTES.

A blank determination should be made on corresponding amounts of reagents treated as above, and the results should be corrected accordingly.

If the copper contents of the alloy is as high as about 3 per cent or over, it prevents a good end point in the tin titration when the tin percentage is low. Under such conditions, just before titrating, add about 1 g. of KI crystals, stir until nearly dissolved and titrate immediately. If allowed to stand too long at this point, trouble may be encountered due to the precipitation of some of the other constituents.

Other forms of pure iron may be employed, but the wire as above specified has been found convenient.

For accurate work it is desirable to reduce and titrate the solution of tin in an atmosphere of CO_2

STANDARD METHODS OF CHEMICAL ANALYSIS OF MANGANESE BRONZE[1]

Serial Designation: B 27 - 19

These methods are issued under the fixed designation B 27; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1918; ADOPTED, 1919.

These methods were approved December 28, 1921, as "Tentative American Standard" by the American Engineering Standards Committee.

GENERAL CONSIDERATIONS.

Methods are given for the determination of lead, using a large sample when lead is present up to about 0.2 per cent. A method is also given for the electrolytic determination of lead and copper in the same small sample when lead is present in amounts over 0.2 per cent.

In this alloy zinc is taken by difference. For a method of determining small amounts of zinc, see Standard Methods of Chemical Analysis of Gun Metal (Serial Designation: B 28) of the American Society for Testing Materials.[2]

DETERMINATION OF COPPER BY THE ELECTROLYTIC METHOD.

APPARATUS FOR ELECTROLYSIS.

Electrodes.—The electrodes recommended are of the stationary and not of the rotating type, as the stationary require less operator's time and there is less chance for erroneous results to be obtained than with the other kind. Rapid and accurate results are obtained with stationary electrodes made from platinum gauze.

[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee B-2 on Non-Ferrous Metals and Alloys.

[2] See p. 711.

Cathodes.—Platinum cathodes may be formed either from plain or perforated sheets, or from wire gauze, and may be either open or closed cylinders. They should give a depositing surface, counting both sides, of approximately 100 sq. cm. Gauze cathodes are recommended, and are best made from gauze containing approximately 400 meshes per sq. cm. (50 meshes per linear inch). The cathode should be stiffened by doubling the gauze for about 3 mm. at the top and at the bottom of the cylinder. The cylinder should be approximately 30 mm. in diameter and 30 mm. in height. The stem should be made from 1.14-mm. or 1.29-mm. wire, flattened and welded the entire width of the gauze; the height over all should be approximately 130 mm., and the gauze should be sand blasted.

Anodes.—Platinum anodes may be of the spiral type when used in the determination of copper by electrolysis, or in the electrolytic determination of lead when it is present in amounts not over 0.2 per cent. When used in electrolytic determination of copper and lead together in samples containing 0.2 per cent lead or over, the anodes should be of wire gauze. Spiral anodes should be made from 1.02-mm. or 1.14-mm. wire formed into a spiral of 7 turns having a height of approximately 51 mm. and a diameter of 16 mm., the length over all being approximately 145 mm. Platinum gauze used in making anodes should contain approximately 400 meshes per sq. cm. (50 meshes per linear inch). The gauze should be formed into closed cylinders approximately 12 mm. in diameter and 30 mm. in height. The cylinders should be stiffened by doubling the gauze for about 3 mm. at the top and at the bottom. The stem should be made from 1.02-mm. or 1.29-mm. wire, flattened and welded the entire width of the gauze; the height over all should be approximately 137 mm., and the gauze should be sand blasted.

METHOD.

In a 150-cc. beaker dissolve 1 g. of bronze in 10 cc. of HNO_3, sp. gr. 1.42. When the action has ceased, evaporate the solution to dryness, and bake thoroughly on the edge of a hot plate. Moisten thoroughly with HNO_3, sp. gr. 1.42, and after digesting for a short time dilute to 50 cc. with hot distilled water, heat to boiling, and allow to stand and settle for about one hour, keeping the temperature just below the boiling point. Filter on double

7-cm. papers, keeping the solution hot, and receive the filtrate in a 200-cc. electrolysis beaker. Wash with boiling hot water. Add to the filtrate 5 cc. of H_2SO_4, sp. gr. 1.84, and evaporate until copious fumes of H_2SO_4 are evolved. Dilute to about 100 cc. with distilled water, add 1.5 cc. of HNO_3, sp. gr. 1.24, insert electrodes, cover with a pair of split watch-glasses and electrolyze. For each solution use a current over night of 0.5 ampere at approximately 10 volts, or else use a current of 4 amperes at approximately 10 volts continued for about $2\frac{1}{2}$ hours. The latter case requires the use of gauze cathodes. When the solution is colorless, wash down cover glasses, electrodes, and sides of beaker, raising the level of the liquid slightly and continue the electrolysis about 15 minutes, noting whether or not copper is deposited on the newly exposed surface of the platinum. If no copper appears, transfer about 1 cc. of the colorless solution to the cavity of a porcelain test plate, and add a few drops of fresh H_2S water. If the slightest discoloration occurs continue the electrolysis, repeating the test. Remove the cathode quickly, rinse it in distilled water and then dip it in two successive baths of alcohol. Shake off the excess alcohol and ignite the remainder by bringing it to the flame of an alcohol lamp. Keep the cathode moving continually as the alcohol burns. Weigh as metallic copper.

Accuracy.—Duplicate determinations should check within 0.10 per cent of copper.

NOTES.

In alloys of the type of manganese bronze, which carry considerable iron, it is impossible to remove the tin quantitatively as metastannic acid (H_2SnO_3), notwithstanding the preliminary baking. Upon testing (by the addition of H_2S water), the liquid in the pits of the test plate may be colored yellow, due to the tin present, but there should be no darkening due to the presence of copper. If the cathode appears dark, as though tin had been deposited on it, dissolve the coating in 10 cc. of HNO_3, sp. gr. 1.42, filter off the tin as before, add to the filtrate 5 cc. of H_2SO_4, sp. gr. 1.84, and redeposit copper by electrolysis. It is rarely necessary thus to purify the deposited copper.

If zinc is to be determined in the alloy be careful to keep the solution quantitative when the electrodes are removed, catching all washings in the beaker containing the electrolyte.

A slight amount of copper is retained by the metastannic acid (H_2SnO_3), which should be recovered in very accurate work but is generally neglected in routine analysis.

DETERMINATION OF LEAD BY THE ELECTROLYTIC METHOD.

(FOR SAMPLES CONTAINING UP TO 0.2 PER CENT OF LEAD.)

METHOD.

In a 250-cc. beaker dissolve 5 g. of bronze in 25 cc. of HNO_3, sp. gr. 1.42. Allow the solution to bake dry on the edge of a hot plate or by standing over night on the steam bath. Add 17 cc. of HNO_3, sp. gr. 1.42, and after digesting for a short time, add 85 cc. of hot water and heat to boiling for a few minutes. Allow the solution to stand for several hours at a temperature just below the boiling point. Filter off the precipitated H_2SnO_3 on double closely woven filter papers, being careful to keep the solution hot throughout the process of filtration. Wash with boiling hot water. Receive the combined filtrate and washings in a 250-cc. beaker. Dilute to about 150 cc. with distilled water and insert electrodes. In the positive terminal use a sand-blasted platinum gauze electrode such as is used for the cathode in the determination of copper: in the negative terminal insert an electrode such as is used for the anode in the determination of copper. Cover with a pair of split watch glasses and electrolyze. For each solution use a current of 1.25 to 1.5 amperes at 10 volts continued for about one hour. Wash down the cover glasses, electrodes and sides of beaker, raising the level of the liquid slightly, and continue the electrolysis for 15 minutes. If no darkening of the newly exposed surface of the platinum can be detected the lead has been entirely deposited. Continue the electrolysis until no darkening of the platinum can be detected when the current has been passed for 15 minutes after the level of the liquid has been raised.

When the lead has been entirely deposited, remove the anode quickly, rinse it in distilled water and then in alcohol, and dry it at 210° C. for one-half hour. Weigh as PbO_2, using the factor for lead 0.8643 instead of the theoretical value.

Accuracy.—Duplicate determinations should check within 0.01 per cent of lead. Results obtained by this method are likely to be about 0.01 per cent too high. For exceptionally accurate or investigation work redissolve the coating from the electrode and determine the lead as sulfate. See the "Determination of Lead as Sulfate."[1]

[1] See p. 704.

NOTES.

It is impossible to remove the tin quantitatively as H_2SnO_3 in the case of alloys containing over 0.25 per cent of iron, and traces of tin are sometimes found in the PbO_2 deposit. Small amounts of manganese also are occasionally deposited with the PbO_2. Tin and manganese are rarely present in the PbO_2 in amounts which necessitate a purification of the deposit.

In this and the following method a slight amount of lead may be retained by the H_2SnO_3. This should be recovered in very accurate work, but is neglected in routine analysis.

DETERMINATION OF LEAD AS SULFATE.

(FOR SAMPLES CONTAINING UP TO 0.2 PER CENT OF LEAD.)
(OPTIONAL.)

SOLUTIONS REQUIRED.

"*Lead Acid.*"—Mix 300 cc. of H_2SO_4, sp. gr. 1.84, and 1800 cc. of distilled water. Dissolve 1 g. of lead acetate, c. p., in 300 cc. of distilled water and add this to the hot solution, stirring meanwhile. Let stand at least 24 hours and syphon through a thick asbestos filter.

Dilute Alcohol for Washing.—Mix equal parts of denatured alcohol and distilled water.

METHOD.

In a 250-cc. beaker dissolve 5 g. of bronze in 25 cc. of HNO_3, sp. gr. 1.42. Allow the solution to bake dry on the edge of a hot plate, or by standing over night on the steam bath. Add 17 cc. of HNO_3, sp. gr. 1.42, and after digesting for a short time, add 85 cc. of hot water and heat to boiling for a few minutes. Allow the solution to stand for several hours at a temperature just below the boiling point. Filter off the precipitated H_2SnO_3 on double closely woven filter papers, being careful to keep the solution hot throughout the process of filtration. Wash with boiling hot water. To the combined filtrate and washings add 120 cc. of lead acid, and evaporate until copious fumes of H_2SO_4 are evolved. Cool, add 105 cc. of distilled water to dissolve the salts and to make the acid concentration the same as in lead acid, heat to boiling, and allow to cool and settle for 5 hours, or over night if convenient. Filter on a weighed porcelain Gooch crucible and wash with lead acid.

Wash out the lead acid with dilute alcohol, set the Gooch crucible inside a porcelain crucible, dry and ignite for 5 minutes at the full heat of a Tirrill burner, cool and weigh as $PbSO_4$, which contains 68.29 per cent lead.

Accuracy.—Duplicate determinations should check within 0.01 per cent of lead. Results obtained by this method are likely to be about 0.01 per cent too low.

NOTE.

It is impossible to remove the tin quantitatively as H_2SnO_3 in the case of alloys containing over 0.25 per cent of iron, but by the preliminary baking and long standing, most of the H_2SnO_3 is precipitated.

DETERMINATION OF COPPER AND LEAD SIMULTANEOUSLY BY THE ELECTROLYTIC METHOD.

(FOR SAMPLES CONTAINING OVER 0.2 PER CENT OF LEAD.)

METHOD.

In a 150-cc. beaker dissolve 1 g. of bronze in 10 cc. of HNO_3, sp. gr. 1.42. When the action has ceased, evaporate the solution to dryness, and bake thoroughly on the edge of a hot plate. Add 10 cc. of HNO_3, sp. gr. 1.42, and after digesting for a short time add 50 cc. of hot distilled water, heat to boiling, and allow to stand and settle for about one hour, keeping the temperature just below the boiling point. Filter on double 7-cm. filter papers, keeping the solution hot, and receive the filtrate in a 200-cc. electrolysis beaker. Wash with boiling hot water, dilute to about 100 cc. and insert electrodes. In the positive terminal insert one of the platinum gauze anodes previously described, and in the negative terminal insert a platinum gauze cathode. Cover with a pair of split watch glasses and electrolyze, using a current of from 3 to 5 amperes at approximately 10 volts for each solution. After about 45 minutes the lead will have been entirely deposited on the anode as PbO_2; without interrupting the current add to the electrolyte 3 to 4 cc. of H_2SO_4, sp. gr. 1.84, and continue the electrolysis. When the solution is colorless, wash down cover glasses, electrodes and sides of beaker, raising the level of the liquid slightly, and continue the passage of the current about 15 minutes, noting whether or not copper is deposited on the newly exposed surface of the platinum. If no copper appears, transfer about 1 cc. of the colorless solution to

the cavity of a porcelain test plate, and add a few drops of fresh H_2S water. If the slightest discoloration occurs continue the electrolysis until there is no discoloration whatever upon repeating the test. Remove the solution from the electrodes quickly without interrupting the current. Rinse the electrodes in distilled water and then dip them in two successive baths of alcohol. Dry the anode at 210° C. for one-half hour. Weigh as PbO_2, using the factor for lead 0.8643 instead of the theoretical value. Shake off the excess alcohol from the cathode and ignite the remainder by bringing it to the flame of an alcohol lamp. Keep the cathode moving continually while the alcohol burns. Weigh as metallic copper.

Accuracy.—Duplicate copper determinations should check within 0.10 per cent of copper. Duplicate lead determinations should check within 0.02 per cent of lead. Lead results obtained by this method are likely to be about 0.01 per cent too high. See notes under the "Determination of Lead by the Electrolytic Method."[1]

DETERMINATION OF TIN.

SOLUTIONS REQUIRED.

Dilute Hydrochloric Acid.—Mix 500 cc. of HCl, sp. gr. 1.20, and 500 cc. of distilled water.

Dilute Sulfuric Acid.—Mix 300 cc. of H_2SO_4, sp.gr., 1.84, and 600 cc. of distilled water.

Dilute Ammonia.—Mix 100 cc. of NH_4OH, sp. gr. 0.90, and 900 cc. of distilled water.

Ammonium-Acetate Solution for Washing.—Dissolve 10 g. of ammonium acetate in 300 cc. of distilled water. Make slightly acid with acetic acid and saturate with H_2S gas.

METHOD.

In a 150-cc. beaker dissolve 2 g. of bronze in a mixture of 10 cc. of HCl, sp. gr. 1.20, and 5 cc. of HNO_3, sp. gr. 1.42. Dilute to about 75 cc. with distilled water. Add NH_4OH, sp. gr. 0.90, until the basic salts of copper have dissolved and the solution has become a deep blue. Boil and allow to settle, and filter on a closely woven filter paper. Wash with dilute ammonia and with hot water. Dissolve the precipitate on the filter with hot dilute HCl. Dilute the solution to about 100 cc. Add NH_4OH, sp. gr. 0.90, until a permanent precipitate forms.

[1] See p. 703.

Heat the solution to boiling, allow to settle, filter and wash as before. Dissolve the precipitate on the filter with boiling hot dilute H_2SO_4, washing the paper very thoroughly with this acid. Add NH_4OH, sp. gr. 0.90, cautiously until the precipitate which forms at first dissolves rather slowly. Allow the solution to stand for some hours and if any lead sulfate forms filter it off. Dilute the solution to about 200 cc. and saturate it with H_2S gas. Filter the precipitated tin sulfide off on double papers and wash with ammonium-acetate solution, retaining the filtrate and washings for the iron determination. Dry the precipitate and place it with the papers in a porcelain crucible which projects part way through a hole in a piece of asbestos board. Heat slowly until any free sulfur has been driven off, but without allowing the sulfur to burn. When the sulfur has been expelled, place the crucible on a triangle and ignite slowly at first and finally at the full heat of the burner. If the precipitate weighs more than 20 mg. heat to constant weight, using a blast lamp. Weigh as SnO_2, which contains 78.81 per cent of tin.

Accuracy.—Duplicate determinations should check within 0.06 per cent of tin.

NOTES.

If, during ignition, the sulfur is allowed to burn, some tin sulfate may be formed, causing high results. On the other hand, low results may be caused by too high heat, which causes spattering and volatilizes some tin sulfide.

Tin and iron are best determined on the same sample, retaining the filtrate from the tin sulfide precipitate to use for the iron determination.

DETERMINATION OF IRON.

SOLUTIONS REQUIRED.

See "Determination of Tin,"[1] and the following:

Dilute Sulfuric Acid for Reductor.—Mix 50 cc. of H_2SO_4, sp. gr. 1.84, and 1000 cc. of distilled water. This solution is used boiling hot.

Potassium Permanganate.—Dissolve 0.2 g. of $KMnO_4$ in water, filter through asbestos, and dilute to 1000 cc. with distilled water. Standardize against 0.020-g. portions of pure sodium oxalate. Each cubic centimeter is equivalent to approximately 0.00033 g. of iron.

METHOD.

Proceed exactly as in the "Determination of Tin"[1] through the filtration and washing of the precipitated tin sulfide. Com-

[1] See p. 706.

bine the filtrate and washings from the tin sulfide precipitate and boil until all H_2S is expelled. Add HNO_3, sp. gr. 1.42, until the iron is oxidized, which is shown by the solution becoming clear and of a yellowish color. Add about 5g. of NH_4Cl, then NH_4OH, sp. gr. 0.90, until a permanent precipitate forms. Boil, allow to settle, filter on a loosely woven filter paper and wash with dilute ammonia and with hot water. Dissolve the precipitate on the paper with hot dilute HCl and add NH_4OH, sp. gr. 0.90, to the solution again until a permanent precipitate forms. Boil, allow to settle, filter on a loosely woven filter paper, and wash with dilute ammonia and with hot water until all NH_4Cl is removed. Dissolve the precipitate and wash the filter paper with 100 cc. of dilute H_2SO_4 for reductor. Pass the solution through a Jones reductor, wash first with 150 cc. of the H_2SO_4 for reductor and then with 100 cc. of distilled water. Titrate with the standard $KMnO_4$ solution.

Accuracy.—Duplicate determinations should check within 0.03 per cent of iron.

NOTES.

A blank determination should be made on corresponding amounts of acid and water passed through the reductor and the results should be corrected accordingly. About 0.5 cc. of the permanganate will be required to give a permanent coloration to the solution.

A small quantity of liquid should always be left in the reductor funnel, and air should never be allowed to enter the body of the reductor.

For description and further details of use of reductor see "The Chemical Analysis of Iron" by A. A. Blair, or "Quantitative Chemical Analysis" by H. P. Talbot.

DETERMINATION OF MANGANESE BY THE PERSULFATE METHOD.

SOLUTIONS REQUIRED.

Solution for Dissolving.—Mix 500 cc. of H_2SO_4, sp. gr. 1.84, 200 cc. of HNO_3, sp. gr. 1.42, and 1700 cc. of distilled water.

Silver Nitrate.—Dissolve 1.33 g. of $AgNO_3$ in 1000 cc. of distilled water.

Stock Sodium Arsenite.—To 15 g. of arsenious oxide (As_2O_3) in a 300-cc. Erlenmeyer flask, add 45 g. of Na_2CO_3 and 150 cc. of distilled water. Heat the flask and contents on the steam bath until the As_2O_3 is dissolved. Cool the solution, filter and make up to 1000 cc. with distilled water.

Standard Sodium Arsenite.—Mix 200 cc. of stock sodium-arsenite solution with 2500 cc. of distilled water, and standardize against a steel or iron of known manganese content as determined by the Bismuthate Method, or standardize against one of the Bureau of Standards' standard irons or steels. One cubic centimeter of this solution should be equivalent to approximately 0.00050 g. of manganese.

Ammonium Persulfate.—Dissolve 60 g. of ammonium persulfate in 1000 cc. of distilled water.

METHOD.

In a 250-cc. Erlenmeyer flask dissolve 1 g. of bronze in 24 cc. of the "solution for dissolving." Allow to stand on a steam bath or hot plate until entirely dissolved, and until the oxides of nitrogen are expelled. Add 15 cc. of $AgNO_3$ solution and 20 cc. of ammonium persulfate and leave on the steam bath until the solution has developed a full permanganate color and no bubbles can be seen to come off when the flask is given a whirling motion. Cool to below 25° C. in running water, and add 50 cc. of cold water. Titrate with standard sodium-arsenite solution to the disappearance of the pink color.

Accuracy.—Duplicate determinations should check within 0.02 per cent of manganese.

NOTES.

Large amounts of permanganic acid are unstable; on that account, samples which contain large amounts of manganese should have correspondingly small samples weighed out. For instance, with metal containing 1.5 per cent of manganese use a 0.10-g. sample, while if metal contains 0.75 per cent manganese use a 0.20-g. sample.

The solution must be cold when it is titrated, for high temperatures cause low results to be obtained.

DETERMINATION OF MANGANESE BY THE BISMUTHATE METHOD. (OPTIONAL.)

SOLUTIONS REQUIRED.

Nitric Acid (1:3).—Mix 250 cc. of HNO_3, sp. gr. 1.42, and 750 cc. of distilled water.

Nitric Acid for Washing.—Mix 30 cc. of HNO_3, sp. gr. 1.42, and 970 cc. of distilled water.

Ferrous Ammonium Sulfate.—Dissolve 12.4 g. of ferrous

ammonium sulfate crystals in 950 cc. of distilled water, and add 50 cc. of H_2SO_4, sp. gr. 1.84.

Potassium Permanganate.—Dissolve 1 g. of $KMnO_4$ in 1000 cc. of distilled water. Allow it to stand for about one week and then filter it through asbestos. Standardize against 0.10-g. portions of pure sodium oxalate.

METHOD.

In a 250-cc. Erlenmeyer flask dissolve 1 g. of bronze in 50 cc. of HNO_3 (1:3). Without filtering off the H_2SnO_3, cool and add 0.5 g. of sodium bismuthate. Heat for a few minutes until the purple color has disappeared, with or without the precipitation of manganese dioxide. Add a little ferrous ammonium sulfate solution until the solution becomes clear, and boil until the oxides of nitrogen are expelled. Cool, add an excess of sodium bismuthate and agitate for a few minutes. Add 50 cc. of HNO_3 for washing and filter through an alundum crucible or an asbestos pad. Wash with 50 cc. of the HNO_3 for washing. Add from a pipette or a burette 10 cc. of ferrous ammonium sulfate solution and titrate with $KMnO_4$. Owing to the presence of considerable copper, the end point is somewhat different from the normal pink color.

In exactly the same manner carry through a blank determination, using the same amounts of HNO_3 and sodium bismuthate as was done with the regular sample. Finally add exactly 10 cc. of ferrous ammonium sulfate solution and titrate with $KMnO_4$. The difference between the two titrations is due to the manganese. Since one manganese as permanganate oxidized five irons, the iron value of the permanganate multiplied by the factor $\frac{Mn}{5\,Fe}$ (or 0.1967) gives the value in terms of manganese.

Accuracy.—Duplicate determinations should check within 0.02 per cent of manganese.

NOTES.

Instead of employing the method of reducing the permanganic acid by means of standardized ferrous ammonium sulfate solution and titrating the excess of this reagent, it is possible to reduce the permanganic acid by standard sodium-arsenite solution. See "Determination of Manganese by the Persulfate Method."[1]

The filtrate from the bismuthate must be perfectly clear, as the least particle of bismuthate carried into the filtrate will vitiate the results.

[1] See p. 708.

STANDARD METHODS OF CHEMICAL ANALYSIS OF GUN METAL[1]

Serial Designation: B 28 – 19

These methods are issued under the fixed designation B 28; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1918; ADOPTED, 1919.

These methods were approved December 28, 1921, as "Tentative American Standard" by the American Engineering Standards Committee.

GENERAL CONSIDERATIONS.

Phosphorus should not be present in this alloy except in very small amounts. A rapid qualitative test for it is given whereby it is easily seen whether or not it is necessary to make a correction for its presence in the determination of tin.

A special method is also given for the determination of tin in alloys such as phosphor-bronze which contain considerable phosphorus.

DETERMINATION OF COPPER BY THE ELECTROLYTIC METHOD.

APPARATUS FOR ELECTROLYSIS.

Electrodes.—The electrodes recommended are of the stationary and not of the rotating type, as the stationary require less operator's time and there is less chance for erroneous results to be obtained than with the other kind. Rapid and accurate results are obtained with stationary electrodes made from platinum gauze.

Cathodes.—Platinum cathodes may be formed either from plain or perforated sheets, or from wire gauze, and may be either open or closed cylinders. They should give a depositing surface, counting both sides, of approximately 100 sq. cm. Gauze cathodes are recommended, and are best made from gauze containing approximately 400 meshes per sq. cm. (50 meshes per

[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee B-2 on Non-Ferrous Metals and Alloys.

linear inch). The cathode should be stiffened by doubling the gauze for about 3 mm. at the top and at the bottom of the cylinder. The cylinder should be approximately 30 mm. in diameter and 30 mm. in height. The stem should be made from 1.14-mm. or 1.29-mm. wire, flattened and welded the entire width of the gauze; the height over all should be approximately 130 mm., and the gauze should be sand blasted.

Anodes.—Platinum anodes may be of the spiral type when used in the determination of copper by electrolysis, or in the electrolytic determination of lead when it is present in amounts not over 0.2 per cent. When used in electrolytic determination of copper and lead together in samples containing 0.2 per cent lead or over, the anodes should be of wire gauze. Spiral anodes should be made from 1.02-mm. or 1.14-mm. wire formed into a spiral of 7 turns having a height of approximately 51 mm. and a diameter of 16 mm., the length over all being approximately 145 mm. Platinum gauze used in making anodes should contain approximately 400 meshes per sq. cm. (50 meshes per linear inch). The gauze should be formed into closed cylinders approximately 12 mm. in diameter and 30 mm. in height. The cylinders should be stiffened by doubling the gauze for about 3 mm. at the top and at the bottom. The stem should be made from 1.02-mm. or 1.29-mm. wire, flattened and welded the entire width of the gauze; the height over all should be approximately 137 mm., and the gauze should be sand blasted.

METHOD.

In a 150-cc. beaker dissolve 1 g. of gun metal in 10 cc. of HNO_3, sp. gr. 1.42. When the action has ceased, boil until the oxides of nitrogen are expelled, add 50 cc. of hot distilled water, and allow to stand and settle for about one hour, keeping the temperature just below the boiling point. Filter on double 7-cm. ashless papers, being careful to keep the solution hot throughout the process of filtration, and receiving the filtrate in a 200-cc. beaker of the tall type used in electrolysis. Wash with boiling hot water. Retain the papers containing the precipitate for subsequent use in the tin determination.

Add to the filtrate 5 cc. of H_2SO_4, sp. gr. 1.84, and determine copper by electrolysis, retaining the electrolyte, after the removal of the copper, for the subsequent determination of zinc. See the "Determination of Copper by the Electrolytic Method," Standard Methods of Chemical Analysis of Man-

ganese Bronze (Serial Designation: B 27) of the American Society for Testing Materials.[1]

Accuracy.—Duplicate determinations should check within 0.10 per cent of copper.

NOTES.

Copper, zinc, and tin are conveniently determined on the same sample, tin being first removed, and any zinc tested for after copper has been deposited by electrolysis.

If the solution becomes cool during the first filtration some of the metastannic acid (H_2SnO_3) may dissolve.

DETERMINATION OF TIN.

(FOR SAMPLES FREE FROM PHOSPHORUS.)

METHOD.

See the "Determination of Copper by the Electrolytic Method."[2]

Use the papers containing the H_2SnO_3 which was filtered off in the Determination of Copper by the Electrolytic Method. Ignite the papers with the precipitate, while moist, in a porcelain or platinum crucible, slowly at first, and finally at the full heat of the burner. If the precipitate weighs more than 20 mg. heat to constant weight, using a blast lamp. Weigh as SnO_2, which contains 78.81 per cent of tin.

Accuracy.—Duplicate determinations should check within 0.04 per cent of tin.

NOTES.

This method is not accurate for alloys which contain arsenic, antimony or phosphorus, or which contain over 0.25 per cent of iron. The SnO_2 may be contaminated with a slight amount of copper and purification is required in very accurate work, but is generally neglected in routine analysis.

The ignited tin oxide contains any phosphorus which may be present in the alloy. The following test is here made use of to detect phosphorus and to estimate its amount, if any is found.

QUALITATIVE TEST FOR PHOSPHORUS.

SOLUTIONS REQUIRED.

Ferric Chloride.—Dissolve 25 g. of ferric chloride in 100 cc. of distilled water, and add 25 cc. of HCl, sp. gr. 1.20.

[1] See p. 700. [2] See p. 711.

METHOD.

Dip a small piece of the alloy into a few cubic centimeters of ferric chloride for about 10 seconds, and then rinse it in running water. Alloys containing phosphorus are darkened noticeably where they have been dipped; alloys containing over 0.25 per cent of phosphorus are rendered almost black by this test. Arsenic and antimony act in a manner similar to phosphorus, but should not be present in this alloy.

CORRECTION FOR PHOSPHORUS.

In alloys containing up to 0.20 per cent of phosphorus a correction for its presence in the ignited tin oxide may be made according to the following empirical method. From the phosphorus content of the alloy, which must be determined on a separate sample, compute the weight of P_2O_5 and subtract two-thirds of this weight from the weight of the ignited tin oxide containing phosphorus. The remainder is considered as pure SnO_2, which contains 78.81 per cent of tin. The factor for converting phosphorus to $\frac{2}{3} \times P_2O_5$ is 152.6 per cent or approximately one and one-half times the phosphorus content of the sample.

If the alloy contains over 0.20 per cent of phosphorus a special method for the determination of tin should be used.

Arsenic and antimony should not be present in weighable amounts in the tin oxide resulting from a sample of gun metal.

Iron may be present in the H_2SnO_3 in very small amounts, but its weight is negligible in this determination.

In alloys which contain over 0.25 per cent of iron, use the method for the "Determination of Tin in Manganese Bronze," Standard Methods of Chemical Analysis of Manganese Bronze (Serial Designation: B 27) of the American Society for Testing Materials.[1]

DETERMINATION OF TIN.

(FOR SAMPLES CONTAINING PHOSPHORUS.)

SOLUTIONS REQUIRED.

Yellow Ammonium Sulfide.—Saturate 150 cc. of NH_4OH, sp. gr. 0.90, with H_2S gas and then add 50 cc. more NH_4OH.

[1] See p. 706.

Dissolve in this solution 3 or 4 g. of sulfur flour and about 1 g. of NH_4Cl. Make up this solution freshly and filter immediately before using.

Dilute Yellow Ammonium Sulfide for Washing.—Mix 20 cc. of yellow ammonium sulfide, prepared as above, and 400 cc. of distilled water.

Ammonium Acetate for Washing.—Dissolve 10 g. of ammonium acetate in 300 cc. of distilled water, make slightly acid with acetic acid and saturate with H_2S gas.

METHOD.

See the "Determination of Copper by the Electrolytic Method."[1]

Use the papers containing the freshly filtered H_2SnO_3 which was filtered off in the Determination of Copper by the Electrolytic Method. Transfer the papers with the precipitate to a 150-cc. beaker, and cover them with 40 to 50 cc. of yellow ammonium sulfide. Warm for about 15 minutes, or until the H_2SnO_3 has dissolved. Filter and wash thoroughly with dilute yellow ammonium sulfide. Acidify the combined filtrate and washings cautiously with 50-per-cent acetic acid. Warm, and allow the precipitated tin sulfide and sulfur to settle. Filter on double papers and wash with ammonium-acetate solution. Dry the precipitate, and place it with the papers in a porcelain crucible which projects part way through a hole in a piece of asbestos board. Heat slowly until the free sulfur has been driven off, but without allowing the sulfur to burn. When the sulfur has been expelled, place the crucible on a triangle and ignite slowly at first, and finally at the full heat of the burner. If the precipitate weighs more than 20 mg., heat to constant weight, using a blast lamp. Weigh as SnO_2, which contains 78.81 per cent of tin.

Accuracy.—Duplicate determinations should check within 0.06 per cent of tin.

NOTES.

If during the first filtration the solution becomes cool, some of the H_2SnO_3 may dissolve.

During ignition, if the sulfur is allowed to burn, some tin sulfate may be formed, causing high results. On the other hand, low results may be caused by too high heat, which causes spattering, and volatilizes some tin sulfide.

[1] See p. 711.

DETERMINATION OF LEAD

BY THE

ELECTROLYTIC METHOD.

(FOR SAMPLES CONTAINING UP TO 0.2 PER CENT OF LEAD.)

METHOD.

In a 250-cc. beaker dissolve 5 g. of gun metal in 25 cc. of HNO_3, sp. gr. 1.42. Allow the solution to bake dry on the edge of a hot plate or by standing over night on the steam bath. Add 17 cc. of HNO_3, sp. gr. 1.42, and after digesting for a short time, add 85 cc. of hot water and heat to boiling for a few minutes. Allow the solution to stand for several hours at a temperature just below the boiling point. Filter off the precipitated H_2SnO_3 on double closely woven filter papers, being careful to keep the solution hot throughout the process of filtration. Wash with boiling hot water. Receive the combined filtrate and washings in a 250-cc. beaker. Dilute to about 150 cc. with distilled water and insert electrodes. In the positive terminal use a sand-blasted platinum gauze electrode such as is used for the cathode in the determination of copper; in the negative terminal insert an electrode such as is used for the anode in the determination of copper. Cover with a pair of split watch glasses and electrolyze. For each solution use a current of 1.25 to 1.5 amperes at 10 volts continued for about one hour. Wash down the cover glasses, electrodes and sides of beaker, raising the level of the liquid slightly, and continue the electrolysis for 15 minutes. If no darkening of the newly exposed surface of the platinum can be detected the lead has been entirely deposited. Continue the electrolysis until no darkening of the platinum can be detected when the current has been passed for 15 minutes after the level of the liquid has been raised.

When the lead has been entirely deposited, remove the anode quickly, rinse it in distilled water and then in alcohol, and dry it at 210° C. for one-half hour. Weigh as PbO_2, using the factor for lead 0.8643 instead of the theoretical value.

Accuracy.—Duplicate determinations should check within 0.01 per cent of lead. Results obtained by this method are likely to be about 0.01 per cent too high. For exceptionally accurate or investigation work redissolve the coating from the

electrode and determine the lead as sulfate. See the "Determination of Lead as Sulfate," below.

NOTES.

It is impossible to remove the tin quantitatively as H_2SnO_3 in the case of alloys containing over 0.25 per cent of iron, and traces of tin are sometimes found in the PbO_2 deposit. Small amounts of manganese also are occasionally deposited with the PbO_2. Tin and manganese are rarely present in the PbO_2 in amounts which necessitate a purification of the deposit.

DETERMINATION OF LEAD AS SULFATE.

(FOR SAMPLES CONTAINING UP TO 0.2 PER CENT OF LEAD.)
(OPTIONAL.)

SOLUTIONS REQUIRED.

"Lead Acid."—Mix 300 cc. of H_2SO_4, sp. gr. 1.84, and 1800 cc. of distilled water. Dissolve 1 g. of lead acetate, c. p., in 300 cc. of distilled water and add this to the hot solution, stirring meanwhile. Let stand at least 24 hours and syphon through a thick asbestos filter.

Dilute Alcohol for Washing.—Mix equal parts of denatured alcohol and distilled water.

METHOD.

In a 250-cc. beaker dissolve 5 g. of gun metal in 25 cc. of HNO_3, sp. gr. 1.42. Allow the solution to bake dry on the edge of a hot plate, or by standing over night on the steam bath. Add 17 cc. of HNO_3, sp. gr. 1.42, and after digesting for a short time, add 85 cc. of hot water and heat to boiling for a few minutes. Allow the solution to stand for several hours at a temperature just below the boiling point. Filter off the precipitated H_2SnO_3 on double closely woven filter papers, being careful to keep the solution hot throughout the process of filtration. Wash with boiling hot water. To the combined filtrate and washings add 120 cc. of lead acid, and evaporate until copious fumes of H_2SO_4 are evolved. Cool, add 105 cc. of distilled water to dissolve the salts and to make the acid concentration the same as in lead acid, heat to boiling, and allow to cool and settle for 5 hours, or over night if convenient. Filter

on a weighed porcelain Gooch crucible and wash with lead acid. Wash out the lead acid with dilute alcohol, set the Gooch crucible inside a porcelain crucible, dry and ignite for 5 minutes at the full heat of a Tirrill burner, cool and weigh as $PbSO_4$, which contains 68.29 per cent lead.

Accuracy.—Duplicate determinations should check within 0.01 per cent of lead. Results obtained by this method are likely to be about 0.01 per cent too low.

NOTE.

It is impossible to remove the tin quantitatively as H_2SnO_3 in the case of alloys containing over 0.25 per cent of iron, but by the preliminary baking and long standing, most of the H_2SnO_3 is precipitated.

DETERMINATION OF ZINC.

SOLUTIONS REQUIRED.

Dilute Hydrochloric Acid.—Mix 500 cc. of HCl, sp. gr. 1.20 and 500 cc. of distilled water.

METHOD.

See the "Determination of Copper by the Electrolytic Method."[1]

After the copper has been completely deposited by electrolysis, quickly remove the cathode and wash it thoroughly in distilled water, catching the washings in the beaker containing the electrolyte. Heat the solution and saturate with H_2S gas. Filter off any precipitate, and boil the solution to expel H_2S. Make the solution barely alkaline with NH_4OH, and add 25 cc. of 85-per-cent formic acid. Dilute the solution with distilled water to 300 cc., heat to boiling, and saturate with H_2S gas. Filter and wash with hot water. Dissolve the precipitate with hot dilute HCl, and transfer the solution to a weighed platinum or porcelain dish or crucible. Add a few drops of H_2SO_4, sp. gr. 1.84, and evaporate the solution until copious fumes escape. If the solution is not clear and colorless, cool, add a few cubic centimeters of HNO_3, sp. gr. 1.42, and again evaporate the solution until fumes of H_2SO_4 come off freely. Repeat the treatment with HNO_3 if necessary, until the organic matter is destroyed, and the solution is colorless. Remove the excess of H_2SO_4 by heating the dish cautiously, and finally heat to dull

[1] See p. 711.

redness. Weigh as zinc sulfate, which contains 40.49 per cent of zinc.

Accuracy.—Duplicate determinations should check within 0.05 per cent of zinc.

DETERMINATION OF PHOSPHORUS BY THE ALKALIMETRIC METHOD.

SOLUTIONS REQUIRED.

Nitric Acid for Dissolving.—Mix 1000 cc. of HNO_3, sp. gr. 1.42, and 1200 cc. of distilled water.

Nitric Acid for Washing.—Mix 20 cc. of HNO_3, sp. gr. 1.42, and 1000 cc. of distilled water.

Ammonium Molybdate.

Solution No. 1.—Place in a beaker 100 g. of 85-per-cent molybdic acid, mix it thoroughly with 240 cc. of distilled water, add 140 cc. of NH_4OH, sp. gr. 0.90, filter and add 60 cc. of HNO_3, sp. gr. 1.42.

Solution No. 2.—Mix 400 cc. of HNO_3, sp. gr. 1.42, and 960 cc. of distilled water.

When the solutions are cold, add solution No. 1 to solution No. 2, stirring constantly; then add 0.1 g. of ammonium phosphate dissolved in 10 cc. of distilled water and let stand at least 24 hours before using.

Potassium Nitrate, 1-per-cent.—Dissolve 10 g. of KNO_3 in 1000 cc. of distilled water.

Phenolphthalein Indicator.—Dissolve 0.2 g. of phenolphthalein in 50 cc. of 95-per-cent ethyl alcohol and 50 cc. of distilled water.

Standard Sodium Hydroxide.—Dissolve 6.5 g. of purified NaOH in 1000 cc. of distilled water, add a slight excess of 1-per-cent solution of barium hydroxide, let stand for 24 hours, decant the liquid, and standardize it against a steel of known phosphorus content as determined by the molybdate-magnesia method, so that 1 cc. will be equivalent to 0.01 per cent of phosphorus on the basis of a 2-g. sample (see Notes). Protect the solution from carbon dioxide with a soda-lime tube.

Ferric Chloride.—Dissolve 100 g. of ferric chloride (phosphorus free) in 100 cc. of distilled water.

Standard Nitric Acid.—Mix 10 cc. of HNO_3, sp. gr. 1.42, and 1000 cc. of distilled water. Titrate the solution against standardized NaOH, using phenolphthalein as indicator, and make it equivalent to the NaOH by adding distilled water.

METHOD.

In a 400-cc. casserole dissolve 1 g. of gun metal in 10 cc. of HNO_3, sp. gr. 1.42. Add 20 cc. of HCl, sp. gr. 1.20, and evaporate to dryness. Moisten with HCl, evaporate to dryness again, and bake to dull redness. Moisten with HCl again, add 3 cc. of ferric-chloride solution, and dilute to about 200 cc. with distilled water. Add NH_4OH, sp. gr. 0.90, until the basic salts of copper have dissolved and the solution has become a deep blue. Boil, allow to settle, and filter on a loosely woven filter paper. Wash with dilute ammonia and with hot water. Dissolve the precipitate on the filter with hot dilute HCl, dilute the solution to about 200 cc., add NH_4OH, sp. gr. 0.90, until the precipitate which forms at first dissolves rather slowly, and saturate with H_2S gas. Filter off and reject the precipitate. Boil the filtrate to expel H_2S, and add HNO_3, sp. gr. 1.42, until the iron is oxidized. Add NH_4OH, sp. gr. 0.90, until the solution is alkaline. Boil and filter on a loosely woven filter paper. Wash with dilute ammonia and with hot water. Dissolve the precipitate on the filter with HNO_3 for dissolving, receiving the solution in a 350-cc. Erlenmeyer flask. Add NH_4OH, sp. gr. 0.90, until the iron is entirely precipitated, and then add HNO_3, sp. gr. 1.42, cautiously until the solution just becomes clear. Bring the solution to a temperature of about 80° C., and add 40 cc. of ammonium molybdate at room temperature. Allow to stand for one minute, shake or agitate for 3 minutes, and filter on a 9-cm. paper. Wash the precipitate three times with the 2-per-cent HNO_3 solution to free it from iron, and continue the washing with the 1-per-cent KNO_3 solution until the precipitate and flask are free from acid.

Transfer the paper and precipitate to a solution flask, add 20 cc. of distilled water, 5 drops of phenolphthalein solution as indicator, and an excess of standard NaOH solution. Insert a rubber stopper and shake vigorously until solution of the precipitate is complete. Wash off the stopper with distilled water and determine the excess of NaOH solution by titrating with standard HNO_3 solution. Each cubic centimeter of standard NaOH solution represents 0.02 per cent of phosphorus.

Accuracy.—Duplicate determinations should check within 0.01 per cent of phosphorus.

NOTES.

The ammonium-molybdate solution should be kept in a cool place and should always be filtered before using.

All distilled water used in titration should be freed from carbon dioxide by boiling or otherwise.

Bureau of Standards Standard Steel No. 19 (*a*) is recommended as a suitable steel for standardization of the NaOH solution.

DETERMINATION OF PHOSPHORUS BY THE FERRIC-ALUM METHOD. (OPTIONAL.)

SOLUTIONS REQUIRED.

Ferric Chloride.—Dissolve 100 g. of ferric chloride (phosphorus free) in 100 cc. of distilled water.

Dilute Ammonia.—Mix 100 cc. of NH_4OH, sp. gr. 0.90, and 900 cc. of distilled water.

Dilute Hydrochloric Acid.—Mix 500 cc. of HCl, sp. gr. 1.20, and 500 cc. of distilled water.

Dilute Sulfuric Acid for Dissolving.—Mix 200 cc. of H_2SO_4, sp. gr. 1.84, and 800 cc. of distilled water.

Dilute Sulfuric Acid for Reductor.—Mix 50 cc. of H_2SO_4, sp. gr. 1.84, and 1000 cc. of distilled water. This solution is used boiling hot.

Ammonium Molybdate.

Solution No. 1.—Place in a beaker 100 g. of 85-per-cent molybdic acid, mix it thoroughly with 240 cc. of distilled water, add 140 cc. of NH_4OH, sp. gr. 0.90, filter and add 60 cc. of HNO_3, sp. gr. 1.42.

Solution No. 2.—Mix 400 cc. of HNO_3, sp. gr. 1.42, and 960 cc. of distilled water.

When the solutions are cold, add solution No. 1 to solution No. 2, stirring constantly, then add 0.1 g. of ammonium phosphate dissolved in 10 cc. of distilled water, and let stand at least 24 hours before using.

Acid Ammonium Sulfate.—Mix 25 cc. of H_2SO_4, sp. gr. 1.84, and 1000 cc. of distilled water, and then add 15 cc. of NH_4OH, sp. gr. 0.90.

Ferric Alum.—Dissolve 200 g. of ferric ammonium sulfate crystals in 1950 cc. of distilled water. Add 50 cc. of H_2SO_4, sp. gr. 1.84, and 80 cc. of phosphoric acid, 85 per cent.

Potassium Permanganate.—Dissolve from 3.0 to 3.2 g. of $KMnO_4$ in 1000 cc. of distilled water. Allow the solution to stand for about one week, and then filter it through an asbestos filter. Standardize by using about 0.200-g. portions of pure sodium oxalate.

METHOD.

In a 400-cc. casserole dissolve 1 g. of gun metal in 10 cc. of HNO_3, sp. gr. 1.42. Add 20 cc. of HCl, sp. gr. 1.20, and evaporate to dryness. Moisten with HCl, evaporate to dryness again, and bake to dull redness. Moisten with HCl again, add 3 cc. of ferric chloride solution, and dilute to about 200 cc. with distilled water. Add NH_4OH, sp. gr. 0.90, until the basic salts of copper have dissolved and the solution has become a deep blue. Boil, allow to settle, and filter on a loosely woven filter paper. Wash with dilute ammonia and with hot water. Dissolve the precipitate on the filter with hot dilute HCl, dilute the solution to about 200 cc., add NH_4OH, sp. gr. 0.90, until the precipitate which forms at first dissolves rather slowly, and saturate with H_2S gas. Filter off and reject the precipitate. Boil the filtrate to expel H_2S, and add HNO_3, sp. gr. 1.42, until the iron is oxidized. Add NH_4OH, sp. gr. 0.90, until the solution is alkaline. Boil and filter on a loosely woven filter paper. Wash with dilute ammonia and with hot water. Dissolve the precipitate on the filter with hot dilute H_2SO_4, receiving the solution in a 350-cc. Erlenmeyer flask. Add NH_4OH, sp. gr. 0.90, until the iron is entirely precipitated, and then add HNO_3, sp. gr. 1.42, cautiously until the solution just becomes clear. Bring the solution to a temperature of about 80° C., and add 40 cc. of ammonium molybdate at room temperature. Allow to stand for one minute, shake or agitate for 3 minutes, filter on a 9-cm. paper, and wash very thoroughly (about 25 times) with acid ammonium sulfate. Dissolve the precipitate on the paper using 50 cc. of dilute ammonia. Add sufficient H_2SO_4 to adjust the acidity to 2.5 per cent by volume, and immediately pass the solution through a Jones reductor, which has the reductor tube prolonged and reaching nearly to the bottom of the flask, dipping into 50 cc. of ferric-alum solution. Wash through the reductor with 150 cc. of the H_2SO_4 for reductor and follow

with 100 cc. of distilled water. Titrate with the standard $KMnO_4$ solution.

By this method the molybdenum which in passing through the reductor has been reduced entirely to the form corresponding to the oxide Mo_2O_3, is partially oxidized by the ferric alum, an equivalent amount of iron being reduced to the ferrous condition. The resultant solution is not rapidly oxidized through contact with air during the titration, and the calculations can therefore be made on the Mo_2O_3—$2MoO_3$ basis.

Accuracy.—Duplicate determinations should check within 0.01 per cent of phosphorus.

NOTES.

The ammonium-molybdate solution should be kept in a cool place and should always be filtered before using.

A blank determination should be made on corresponding amounts of acid and water, passing through the reductor into the usual amount of ferric-alum solution in the flask.

A small quantity of liquid should always be left in the reductor funnel, and air should never be allowed to enter the reductor.

For description and further details of the use of reductor see "Chemical Analysis of Iron" by A. A. Blair, or "Quantitative Chemical Analysis" by H. P. Talbot.

STANDARD METHODS OF CHEMICAL ANALYSIS OF BRASS INGOTS AND SAND CASTINGS[1]

Serial Designation: B 45 – 27

These methods are issued under the fixed designation B 45; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1922; ADOPTED, 1923; REVISED, 1927.

In the alloys containing the higher amounts of zinc this element is taken by difference. For determination of smaller amounts of zinc, see the Standard Methods of Chemical Analysis of Bronze Bearing Metal (Serial Designation: B 46) of the American Society for Testing Materials.[2]

DETERMINATION OF COPPER BY THE ELECTROLYTIC METHOD

APPARATUS FOR ELECTROLYSIS

Electrodes.—The electrodes recommended are of the stationary and not of the rotating type, as the stationary require less of the operator's time and there is less chance for erroneous results to be obtained than with the other kind. Rapid and accurate results are obtained with stationary electrodes made from platinum gauze.

Cathodes.—Platinum cathodes may be formed either from plain or perforated sheets, or from wire gauze, and may be either open or closed cylinders. They should give a depositing surface, counting both sides, of approximately 100 sq. cm. Gauze cathodes are recommended, and are best made from gauze containing approximately 400 meshes per sq. cm. (50 meshes per linear inch). The cathode should be stiffened by doubling the gauze for about 3 mm. at the top and at the bottom of the cylinder. The cylinder should be approxi-

[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee B-2 on Non-Ferrous Metals and Alloys.

[2] See p. 738.

mately 30 mm. in diameter and 30 mm. in height. The stem should be made from 1.14-mm. or 1.29-mm. wire, flattened and welded the entire width of the gauze; the height over all should be approximately 130 mm., and the gauze should be sand blasted.

Anodes.—Platinum anodes may be of the spiral type when used in the determination of copper by electrolysis, or in the electrolytic determination of lead when it is present in amounts not over 0.2 per cent. When used in the electrolytic determination of copper and lead together in samples containing 0.2 per cent of lead or over, the anodes should be of wire gauze. Spiral anodes should be made from 1.02–mm. or 1.14-mm. wire formed into a spiral of 7 turns having a height of approximately 51 mm. and a diameter of 16 mm., the length over all being approximately 145 mm. Platinum gauze used in making anodes should contain approximately 400 meshes per sq. cm. (50 meshes per linear inch). The gauze should be formed into closed cylinders approximately 12 mm. in diameter and 30 mm. in height. The cylinders should be stiffened by doubling the gauze for about 3 mm. at the top and at the bottom. The stem should be made from 1.02-mm. or 1.29-mm. wire, flattened and welded the entire width of the gauze; the height over all should be approximately 130 mm., and the gauze should be sand blasted.

METHOD

In a 150-cc. beaker, dissolve 1 g. of brass in 10 cc. of HNO_3 (sp. gr. 1.42). When the action has ceased, evaporate the solution to dryness, and bake thoroughly on the edge of a hot plate. Moisten thoroughly with HNO_3 (sp. gr. 1.42), and after digesting for a short time dilute to 50 cc. with hot distilled water, heat to boiling, and allow to stand and settle for about one hour, keeping the temperature just below the boiling point. Filter on double 7-cm. papers, keeping the solution hot, and receive the filtrate in a 200-cc. electrolysis beaker. Wash with boiling hot water. Add to the filtrate 5 cc. of H_2SO_4 (sp. gr. 1.84), and evaporate until copious fumes of H_2SO_4 are evolved. Dilute to about 100 cc. with distilled water, add 1.5 cc. of HNO_3 (sp. gr. 1.42), insert electrodes, cover with a pair of split watch glasses and electrolyze. For each solution use a current over night of 0.5 ampere at approximately 10 volts, or else use a current of 4 amperes at approximately 10 volts continued for about $2\frac{1}{2}$ hours. The latter case requires the use of gauze cathodes. When the solution is colorless, wash down the cover glasses, electrodes, and sides of the beaker, raising the level of the liquid slightly, and continue the electrolysis about 15 minutes, noting whether or not copper is deposited on the

newly exposed surface of the platinum. If no copper appears, transfer about 1 cc. of the colorless solution to the cavity of a porcelain test plate, and add a few drops of fresh H_2S water. If the slightest discoloration occurs, continue the electrolysis, repeating the test. Remove the cathode quickly, rinse it in distilled water and then dip it in two successive baths of alcohol. Shake off the excess alcohol and ignite the remainder by bringing it to the flame of an alcohol lamp. Keep the cathode moving continually as the alcohol burns. Weigh as metallic copper.

Accuracy.—Duplicate determinations should check within 0.10 per cent of copper.

NOTES

In alloys of this type which carry considerable iron, it is impossible to remove the tin quantitatively as meta-stannic acid (H_2SnO_3), notwithstanding the preliminary baking. Upon testing (by the addition of H_2S water), the liquid in the pits of the test plate may be colored yellow, due to the tin present, but there should be no darkening due to the presence of copper. If the cathode appears dark, as though tin had been deposited on it, dissolve the coating in 10 cc. of HNO_3 (sp. gr. 1.42), filter off the tin as before, add to the filtrate 5 cc. of H_2SO_4 (sp. gr. 1.84), and redeposit the copper by electrolysis. It is rarely necessary thus to purify the deposited copper.

A slight amount of copper is retained by the meta-stannic acid (H_2SnO_3), which should be recovered in very accurate work but is generally neglected in routine analysis.

DETERMINATION OF LEAD

BY THE

ELECTROLYTIC METHOD

In a 250-cc. beaker, dissolve 1 g. of brass in 25 cc. of HNO_3 (sp. gr. 1.42). Allow the solution to bake dry on the edge of a hot plate or by standing over night on the steam-bath. Add 17 cc. of HNO_3 (sp. gr. 1.42), and after digesting for a short time, add 85 cc. of hot water and heat to boiling for a few minutes. Allow the solution to stand for several hours at a temperature just below the boiling point. Filter off the precipitated H_2SnO_3 on double closely woven filter papers, being careful to keep the solution hot throughout the process of filtration. Wash with boiling water. Receive the combined filtrate and washings in a 250-cc. beaker. Dilute to about 150 cc. with distilled water and insert electrodes. In the positive terminal use a sand-blasted platinum gauze electrode such as is used for the cathode in the "Determination of Copper by the Electrolytic Method";[1] in the negative terminal insert an electrode such as is used for the anode in the "Determination of Copper by the Electrolytic Method."[1]

[1] See p. 724.

Cover with a pair of split watch glasses and electrolyze. For each solution use a current of 1.25 to 1.5 amperes at 10 volts continued for about one hour. Wash down the cover glasses, electrodes and sides of the beaker, raising the level of the liquid slightly, and continue the electrolysis for 15 minutes. If no darkening of the newly exposed surface of the platinum can be detected the lead has been entirely deposited. Continue the electrolysis until no darkening of the platinum can be detected when the current has been passed for 15 minutes after the level of the liquid has been raised.

When the lead has been entirely deposited, remove the anode quickly, rinse it in distilled water and then in alcohol, and dry it at 210° C. for 30 minutes. Weigh as PbO_2, using for lead 0.8643 instead of the theoretical value.

Accuracy.—Duplicate determinations should check within 0.01 per cent of lead. Results obtained by this method are likely to be about 0.01 per cent too high. For exceptionally accurate or investigation work redissolve the coating from the electrode and determine the lead as sulfate. See the "Determination of Lead as Sulfate (Optional)," below.

NOTES

It is impossible to remove the tin quantitively as H_2SnO_3 in the case of alloys containing over 0.25 per cent of iron, and traces of tin are sometimes found in the PbO_2 deposit.

In this and in the following method, a slight amount of lead may be retained by the H_2SnO_3. This should be recovered in very accurate work, but is neglected in a routine analysis.

DETERMINATION OF LEAD AS SULFATE (OPTIONAL)

SOLUTIONS REQUIRED.

"Lead Acid."—Mix 300 cc. of H_2SO_4 (sp. gr. 1.84) and 1800 cc. of distilled water. Dissolve 1 g. of lead acetate, c. p., in 300 cc. of distilled water and add this to the hot solution, stirring meanwhile. Let stand at least 24 hours and siphon through a thick asbestos filter.

Dilute Alcohol for Washing.—Mix equal parts of denatured alcohol and distilled water.

METHOD

In a 150-cc. beaker, dissolve 1 g. of brass in 10 cc. of HNO_3 (sp. gr. 1.42). Allow the solution to bake dry on the edge of a hot

plate, or by standing over night on the steam bath. Add 10 cc. of HNO_3 (sp. gr. 1.42), and after digesting for a short time, add 50 cc. of hot water and heat to boiling for a few minutes. Allow the solution to stand for several hours at a temperature just below the boiling point. Filter off the precipitated H_2SnO_3 on double closely woven filter papers, being careful to keep the solution hot throughout the process of filtration. Wash with boiling hot water. To the combined filtrate and washings, add 40 cc. of lead acid, and evaporate until copious fumes of H_2SO_4 are evolved. Cool, add 35 cc. of distilled water to dissolve the salts and to make the acid concentration the same as in lead-acid, heat to boiling, and allow to cool and settle for 5 hours, or over night if convenient. Filter on a weighed porcelain Gooch crucible and wash with lead acid. Wash out the lead acid with dilute alcohol, set the Gooch crucible inside a porcelain crucible, dry and ignite for 5 minutes at the full heat of a Tirrill burner, cool and weigh as $PbSO_4$, which contains 68.29 per cent of lead.

Accuracy.—Duplicate determinations should check within 0.01 per cent of lead. Results obtained by this method are likely to be about 0.01 per cent too low.

NOTES

Copper and lead may be determined on the same samples if so desired. In such a case, after filtering off the lead sulfate and washing with lead-acid, and before washing with dilute alcohol, remove the filtrate, add 3 cc. of HNO_3 (sp. gr. 1.42), dilute to 120 cc. and determine copper by electrolysis. See the "Determination of Copper by the Electrolytic Method."[1]

It is impossible to remove the tin quantitatively as H_2SnO_3 in the case of alloys containing over 0.25 per cent of iron, but by the preliminary baking and long standing, most of the H_2SnO_3 is precipitated.

DETERMINATION OF COPPER AND LEAD SIMULTANEOUSLY BY THE ELECTROLYTIC METHOD

METHOD

In a 150-cc. beaker, dissolve 1 g. of brass in 10 cc. of HNO_3 (sp. gr. 1.42). When the action has ceased, evaporate the solution to dryness, and bake thoroughly on the edge of a hot plate. Add 10 cc. of HNO_3 (sp. gr. 1.42), and after digesting for a short time add 50 cc. of hot distilled water, heat to boiling, and allow to stand and settle for about one hour, keeping the temperature just below the boiling point. Filter on double 7-cm. filter paper, keeping the solution hot, and receive the filtrate in a 200-cc. electrolysis beaker. Wash with boiling water,

[1] See p. 724.

dilute to about 100 cc. and insert electrodes. In the positive terminal insert one of the platinum gauze anodes previously described, and in the negative terminal insert a platinum gauze cathode. Cover with a pair of split watch glasses and electrolyze, using a current of from 3 to 5 amperes at approximately 10 volts for each solution. After about 45 minutes, the lead will have been entirely deposited on the anode as PbO_2; without interrupting the current add to the electrolyte 3 to 4 cc. of H_2SO_4 (sp. gr. 1.84), and continue the electrolysis. When the solution is colorless, wash down the cover glasses, electrodes and sides of the beaker, raising the level of the liquid slightly, and continue the passage of the current for about 15 minutes, noting whether or not copper is deposited on the newly exposed surface of the platinum. If no copper appears, transfer about 1 cc. of the colorless solution to the cavity of a porcelain test plate, and add a few drops of fresh H_2S water. If the slightest discoloration occurs, continue the electrolysis until there is no discoloration whatever upon repeating the test. Remove the solution from the electrodes quickly without interrupting the current. Rinse the electrodes in distilled water and then dip them in two successive baths of alcohol. Dry the anode at 210° C. for 30 minutes. Weigh as PbO_2, using the factor for lead 0.8643 instead of the theoretical value. Shake off the excess alcohol from the cathode and ignite the remainder by bringing it to the flame of an alcohol lamp. Keep the cathode moving continually while the alcohol burns. Weigh as metallic copper.

Accuracy.—Duplicate copper determinations should check within 0.10 per cent of copper. Duplicate lead determinations should check within 0.02 per cent of lead. Lead results obtained by this method are likely to be about 0.01 per cent too high. See notes under the "Determination of Lead by the Electrolytic Method."[1]

DETERMINATION OF TIN

SOLUTIONS REQUIRED

Dilute Hydrochloric Acid.—Mix 500 cc. of HCl (sp. gr. 1.19) and 500 cc. of distilled water.

Dilute Sulfuric Acid.—Mix 300 cc. of H_2SO_4 (sp. gr. 1.84) and 600 cc. of distilled water.

Dilute Ammonia.—Mix 100 cc. of NH_4OH (sp. gr. 0.90) and 900 cc. of distilled water.

Ammonium Acetate Solution for Washing.—Dissolve 10 g. of

[1] See p. 726.

ammonium acetate in 300 cc. of distilled water. Make slightly acid with acetic acid and saturate with H_2S gas.

METHOD

In a 150-cc. beaker, dissolve 1 g. of brass in a mixture of 10 cc. of HCl (sp. gr. 1.19) and 5 cc. of HNO_3 (sp. gr. 1.42). Dilute to about 75 cc. with distilled water. Add NH_4OH (sp. gr. 0.90) until the basic salts of copper have dissolved and the solution has become a deep blue. Boil and allow to settle and filter on a closely woven filter paper. Wash with dilute ammonia and with hot water. Dissolve the precipitate on the filter with hot dilute HCl. Dilute the solution to about 100 cc. Add NH_4OH (sp. gr. 0.90) until a permanent precipitate forms. Heat the solution to boiling, allow to settle, filter and wash as before. Dissolve the precipitate on the filter with boiling hot dilute H_2SO_4, washing the paper very thoroughly with this acid. Add NH_4OH (sp. gr. 0.90) cautiously until the precipitate which forms at first dissolves rather slowly. Allow the solution to stand for some hours and if any lead sulfate forms filter it off. Dilute the solution to about 200 cc. and saturate it with H_2S gas. Filter the precipitated tin sulfide off on double papers and wash with ammonium acetate solution, retaining the filtrate and washings for the iron determination. Dry the precipitate and place it with the papers in a porcelain crucible which projects part way through a hole in a piece of asbestos board. Heat slowly until any free sulfur has been driven off, but without allowing the sulfur to burn. When the sulfur has been expelled, place the crucible on a triangle and ignite slowly at first and finally at the full heat of the burner. If the precipitate weighs more than 20 mg., heat to constant weight, using a blast lamp. Weigh as SnO_2, which contains 78.81 per cent of tin.

Accuracy.—Duplicate determinations should check within 0.06 per cent of tin.

NOTES

If, during ignition, the sulfur is allowed to burn, some tin sulfate may be formed, causing high results. On the other hand, low results may be caused by too high heat, which causes spattering and volatilizes some tin sulfide.

Tin and iron are best determined on the same sample, retaining the filtrate from the tin sulfide precipitate to use for the iron determination.

In alloys containing an appreciable amount of antimony and in presence of a large excess of tin, the antimony, as determined by titration according to the method given below, should be calculated to Sb_2O_4, and a corresponding amount deducted from the weight of the ignited SnO_2 before calculating to tin.

DETERMINATION OF IRON

SOLUTIONS REQUIRED

See "Determination of Tin."[1]

Dilute Sulfuric Acid for Reductor.—Mix 50 cc. of H_2SO_4 (sp. gr. 1.84) and 1000 cc. of distilled water. This solution is used boiling hot.

Potassium Permanganate.—Dissolve 0.2 g. of $KMnO_4$ in water. filter through asbestos, and dilute to 1000 cc. with distilled water. Standardize against 0.020-g. portions of pure sodium oxalate. Each cubic centimeter is equivalent to approximately 0.00033 g. of iron.

METHOD

Proceed exactly as in the "Determination of Tin"[1] through the filtration and washing of the precipitated tin sulfide. Combine the filtrate and washings from the tin sulfide precipitate and boil until all H_2S is expelled. Add HNO_3 (sp. gr. 1.42) until the iron is oxidized, which is shown by the solution becoming clear and of a yellowish color. Add about 5 g. of NH_4Cl, then NH_4OH (sp. gr. 0.90) until a permanent precipitate forms. Boil, allow to settle, filter on a loosely woven filter paper and wash with dilute ammonia and with hot water. Dissolve the precipitate on the paper with hot dilute HCl and add NH_4OH (sp. gr. 0.90) to the solution again until a permanent precipitate forms. Boil, allow to settle, filter on a loosely woven filter paper, and wash with dilute ammonia and with hot water until all NH_4Cl is removed. Dissolve the precipitate and wash the filter paper with 100 cc. of dilute H_2SO_4 for reductor. Pass the solution through a Jones reductor, wash first with 150 cc. of the H_2SO_4 for reductor and then with 100 cc. of distilled water. Titrate with the standard $KMnO_4$ Solution.

Accuracy.—Duplicate determinations should check within 0.03 per cent of iron.

NOTES

A blank determination should be made on corresponding amounts of acid and water passed through the reductor and the results should be corrected accordingly. About 0.5 cc. of the permanganate will be required to give a permanent coloration to the solution.

A small quantity of liquid should always be left in the reductor funnel, and air should never be allowed to enter the body of the reductor.

For a description and further details of use of reductor see "The Chemical Analysis of Iron" by A. A. Blair, or "Quantitative Chemical Analysis" by H. P. Talbot.

[1] See p. 729.

DETERMINATION OF ANTIMONY BY THE VOLUMETRIC METHOD

SOLUTIONS REQUIRED

Potassium Permanganate.—Dissolve 0.3 g. of potassium permanganate in 1000 cc. of distilled water. Standardize by dissolving 25 mg. of pure antimony in 15 cc. of boiling sulfuric acid and proceed according to the method from this point.

METHOD

In a 250-cc. beaker dissolve 5 g. of brass in 25 cc. of HNO_3 (sp. gr. 1.42). When the action has ceased, boil until the oxides of nitrogen are expelled, add 125 cc. of boiling water and allow to stand and settle for one hour or longer, keeping the temperature just below the boiling point. Filter on double 9-cm. closely woven papers, keeping the solution hot. Wash with boiling water. Discard the filtrate.

Transfer the papers containing the tin and antimony to a 350-cc. Erlenmeyer flask and add 25 cc. of HNO_3 (sp. gr. 1.42), 5 g. of ammonium persulfate, and 15 cc. of H_2SO_4 (sp. gr. 1.84). Boil to strong fumes of SO_3. If the solution is brown, *cool* and add 5 cc. of HNO_3 (sp. gr. 1.42) and a little more (1 g. or less) persulfate, if necessary, and boil again to strong fumes of SO_3. When the solution is colorless, cool, add 20 cc. of distilled water, 20 cc. of HCl (sp. gr. 1.19) and 1 g. of sodium sulfite. Boil gently for 10 minutes to expel SO_2 completely. Dilute with 200 cc. of distilled water and cool to 10 to 12° C. in ice or under running water.

Titrate with standard permanganate solution until the appearance of a decided pink color.

NOTES

1. In alloys containing a large excess of tin, the antimony is precipitated quantitatively with the meta-stannic acid.

2. Ammonium persulfate and nitric acid are used to destroy the filter paper, and subsequent boiling with sulfuric acid effects the solution of the tin and antimony. A mixture of fuming nitric and sulfuric acids might be used to accomplish the same results, but the persulfate mixture is much more efficient.

3. If the solution becomes cool during the first filtration some of the meta-stannic acid may dissolve

4. If arsenic is present, correction should be made for it.

DETERMINATION OF SULFUR

METHOD

Weigh out four 5-g. samples of brass into 250-cc. beakers. Dissolve each in 25 cc. of HNO_3 (sp. gr. 1.42) and boil until the disappearance of red fumes. Add 125 cc. of boiling water and settle for one hour or longer, keeping the temperature just below the boiling point. Filter on double 12.5-cm. closely-woven papers, keeping the solutions hot. Wash with boiling water. Discard the meta-stannic acid precipitates, combine the four filtrates in a tall 700-cc. beaker, and add 0.5 g. of Na_2CO_3, and evaporate the solution until syrupy. Cool somewhat, then dilute to the lip with warm water. There should be present a layer about $\frac{1}{4}$ in. (6 mm.) in thickness, composed of basic salts of copper. Electrolyze, using stationary electrodes, at a current of 4 amperes, or using the Frary solenoid at a current of about 10 amperes. The lead must be removed at the anode as the copper is taken out at the cathode. When copper and lead are out, evaporate the electrolyte to small volume, cover the beaker, add 75 cc. of HCl (sp. gr. 1.19), and boil down to small volume. Add 75 cc. more HCl and evaporate to dryness to dehydrate any silica present. Moisten with about 0.5 cc. of HCl and take up with 20 cc. of hot water. Filter into a small beaker. Heat the filtrate to boiling and add 10 cc. of 5-per-cent $BaCl_2$ solution, drop by drop, with stirring. Allow to settle at least five hours, filter on a small ashless paper, and wash with hot water. Ignite cautiously in a small porcelain or platinum crucible, and then heat to bright redness for 20 minutes. Cool and weigh the $BaSO_4$ and calculate to sulfur.

NOTES

1. Throughout the entire analysis, the utmost precautions must be taken to prevent contamination by sulfur in any form, H_2SO_4 fumes, H_2S, and SO_2 gases especially. All heating with gas burners must be avoided. Run a blank with each analysis, adding all the reagents and subjecting it to the same operations as the beakers containing the drillings. Subtract the amount of $BaSO_4$ found in the blank from that in the determinations. If this blank amounts to 0.002 g., it is a sign of poor work or impure reagents, and the analysis should be repeated. Wash out all beakers, funnels, etc., with distilled water before using.

2. It is necessary to keep the solution containing the meta-stannic acid hot during filtration. If the solution becomes cool, some of the meta-stannic acid may dissolve.

DETERMINATION OF ALUMINUM IN SMALL QUANTITIES

(a) *General Method for Accurate Work*

SOLUTIONS REQUIRED

"*Electrolytic Solution.*"—Mix 300 cc. of HNO_3 (sp. gr. 1.42), 1700 cc. of distilled water, and 500 cc. of H_2SO_4 (sp. gr. 1.84).

Acidified H_2S Water for Washing.—Dilute 10 cc. of HCl (sp. gr. 1.19) with 1000 cc. of distilled water and saturate with H_2S.

Phenylhydrazine Solution for Washing.—Add saturated SO_2 water to a few cubic centimeters of phenylhydrazine until the crystallin sulfite first formed is redissolved, and then add phenylhydrazine, drop by drop, with vigorous agitation, until the odor of SO_2 is no longer perceptible; dilute 5 to 10 cc. of this solution with 100 cc. of hot water and allow to remain at the boiling point for a few minutes so as to get rid of the excess SO_2.

NH_4Cl Solution for Washing (2-per-cent).—Mix 30 cc. of HCl (sp. gr. 1.19) with 200 cc. of distilled water, add methyl red, neutralize with NH_4OH until the solution changes to a distinct yellow, and then dilute to 1000 cc. with water.

METHOD

Dissolve 1 g. of brass or bronze in 35 cc. of "electrolytic solution," dilute with 100 cc. of distilled water and remove copper by electrolysis. Evaporate the electrolyte to fumes of SO_3. (If much tin is present, boil the sulfuric acid solution vigorously for a few minutes.) Cool, and dilute with 100 cc. of water. Filter off $PbSO_4$ and any tin which may be precipitated at this point, washing with hot water. Dilute the filtrate to at least 200 cc.

Pass H_2S into the filtrate for 30 minutes. This will precipitate any copper, lead, tin, arsenic, or antimony which may be present. Allow the sulfides to settle, and filter, washing with acidified H_2S water. Boil the filtrate to one-half volume to expel H_2S, add 3 cc. HNO_3 (sp. gr. 1.42) and boil for a few minutes to oxidize iron.

Precipitate iron and aluminum according to the following[1]: Add 10 cc. of HCl (sp. gr. 1.19) and just neutralize with NH_4OH, using methyl red as an indicator. Boil for two minutes and filter, washing with hot NH_4Cl (2-per-cent). Dissolve the precipitate from the paper with *boiling hot* HCl (1 : 1) and wash alternately with hot water and HCl (1 : 1) into the beaker in which the precipitation was made.

[1] Blum: U. S. Bureau of Standards *Scientific Paper, No. 286*, 1916; *Journal*, American Chemical Society, Vol. 38, p. 1282 (1916).

Re-precipitate the iron and aluminum following the same procedure as before.

Dissolve the precipitate again with hot HCl (1 :1), dilute to 100 cc. with water, make just ammoniacal, then only acid enough to hold iron in solution. Add sufficient saturated solution of ammonium bisulfite to reduce the iron (5 to 20 drops). Add a few drops of methly orange, quickly bring to neutrality with NH_4OH, and then add 6 to 7 drops of HCl (1 :1) in excess. Finally, add from 1 to 3 cc. of phenylhydrazine and stir until the precipitate becomes flaky. The supernatant liquid should be plainly acid to litmus and the precipitate may be colored owing to organic matter. Filter and wash with phenylhydrazine wash solution. Ignite in a weighed platinum crucible, finishing with the blast for 5 minutes. Weigh as Al_2O_3. The weighing should be made rapidly and with the crucible covered as Al_2O_3 is somewhat hygroscopic.

NOTES

1. For small amounts of aluminum, a 5-g. sample should be used. In this case dissolve in 60 cc. of "assay solution" of the following proportions:

7 volumes HNO_3 (sp. gr. 1.42);
10 volumes H_2SO_4 (sp. gr. 1.84);
25 volumes H_2O

2. When phosphorus is present the final precipitate will be $Al_2O_3+P_2O_5$. In this case it is necessary to fuse the residue with Na_2CO_3, dissolve with hot water, acidify with HNO_3, and determine phosphorus in accordance with the Determination of Phosphorus by the Alkalimetric Method of the Standard Methods of Chemical Analysis of Bronze Bearing Metal (Serial Designation: B 46).[1] The phosphorus is calculated to P_2O_5 and subtracted.

3. For accurate work the Al_2O_3 residue is treated with HF and H_2SO_4 for the removal of possible SiO_2.

4. Ammonium bisulfite solution may be prepared by saturating cold NH_4OH (1:1) with SO_2 until yellow.

5. This method is especially satisfactory for small amounts of aluminum in brass or bronze since no reagents are used which may contaminate the precipitate with aluminum, iron or silica. A precipitate with phenylhydrazine gives positive indication of the presence of aluminum.

(*b*) *Rapid Method for Control Work*

SOLUTIONS REQUIRED

Sodium Hydroxide Solution (*2.5-per-cent*).—Dissolve 25 g. of NaOH (free from aluminum) in water and dilute to 1000 cc.

Sodium Sulfide Solution.—Dissolve 150 g. of NaOH (free from aluminum) in 1000 cc. of water, saturate 500 cc. of this solution with hydrogen sulfide, and mix with the remaining 500 cc. of solution.

[1] See p. 747.

Dilute Hydrochloric Acid (1 : 3).—Mix 200 cc. of HCl (sp. gr. 1.19) with 600 cc. of water.

Acidified Hydrogen Sulfide Water.—Dilute 10 cc. of HCl (sp. gr. 1.19) with 1000 cc. of water and saturate the solution with hydrogen sulfide.

Ammonium Chloride Solution (2-per-cent).—Mix 30 cc. of HCl (sp. gr. 1.19) with 200 cc. of water, add methyl red, neutralize with ammonia until the solution changes to a distinct yellow, and then dilute to 1000 cc. with water.

METHOD

Dissolve 2 g. of the sample in 20 cc. of HCl (sp. gr. 1.19) and 5 cc. of HNO_3 (sp. gr. 1.42). Boil the solution to expel chlorine and dilute with 50 cc. of water. Nearly neutralize the cold solution with NaOH solution (2.5-per-cent, or stronger if much free acid is present), and pour it slowly and with constant shaking into a 500-cc. volumetric flask containing 100 cc. of sodium sulfide solution. Dilute to the mark with NaOH solution (2.5-per-cent) and mix thoroughly. Filter on a large, dry, No. 42 Whatman filter paper (or its equivalent) and keep the paper well filled with the solution lest iron be oxidized and dissolved. Reject the first 20 to 25 cc., and catch exactly 250 cc. which will represent 1 g. of sample. In routine analyses of material containing not more than 1 per cent of aluminum, the aliquot portion can be gathered in a 250-cc. graduate.

Transfer the aliquot portion to a 600-cc. beaker, neutralize the solution with dilute HCl (1:3), and finally add 25 cc. in excess. Digest at 40 to 60° C. for 1 hour, filter, and wash the paper and precipitate with acidified H_2S water.

Boil the filtrate and washings to expel H_2S, add a few drops of methyl red indicator, and then dilute ammonia (1:2) until the solution is just distinctly yellow. Boil for 1 to 2 minutes and filter at once through a small filter. Wash the beaker, paper, and precipitate two or three times with hot NH_4Cl solution (2-per-cent) and discard the filtrate. Dissolve the precipitate in 200 cc. of hot dilute HCl (1:3), wash the filter thoroughly with small portions of hot water, and reserve it for the second filtration. Dilute the filtrate to 50 cc., add methyl red, and precipitate with dilute ammonia (1:2) as before. Filter, wash with hot NH_4Cl solution (2-per-cent), ignite, and weigh.

The ignited residue is prone to carry silica and must be purified before weighing as follows: Add one or two drops of water, one drop of diluted H_2SO_4, and 1 to 5 cc. of HF. Evaporate to dryness, increase the heat slowly, and finally heat with a blast lamp or its equivalent.

Weigh as Al_2O_3. The weight of Al_2O_3 corrected for the blank and multiplied by 52.94 gives the percentage of aluminum.

NOTES

The first aluminum hydroxide precipitate will carry down some NaCl and much of any silica that was dissolved in the NaOH solution; hence, it is not safe to omit the second precipitation and the HF treatment. There is no attack on the glassware during the short contact with the weak, cool, alkaline solution. It is, of course, preferable that the NaOH be free from aluminum. The most satisfactory test for it lies in running an analysis with non-ferrous alloys containing no aluminum. Direct test, by acidification followed by precipitation with ammonia, is sufficient if no precipitate is obtained, but is of doubtful value in case one appears, for it may contain other elements, such as iron, which do not affect the results.

If phosphorus is known to be present, the method should be followed through the first addition of ammonia. If aluminum is indicated, re-acidify the solution with HCl, add macerated paper, two drops of methyl orange, and 10 cc. of a solution of diammonium phosphate (10-per-cent). Render the solution just ammoniacal, then just restore the pink color with dilute HCl (1 : 3), heat to boiling, and add 30 cc. of a solution of ammonium acetate (25-per-cent). Boil for 5 minutes, filter on an 11-cm. No. 42 Whatman or similar filter paper, and wash with hot NH_4NO_3 solution (5-per-cent) until 5 cc. of the washings no longer give a test for chlorides with acidified $AgNO_3$. Ignite in platinum or porcelain, heat at approximately 1100° C. for 10 minutes, and weigh as $AlPO_4$. This method is not strictly accurate on account of the uncertain composition of the phosphate, but is sufficiently accurate for all but the most painstaking analyses.

STANDARD METHODS OF CHEMICAL ANALYSIS OF BRONZE BEARING METAL[1]

Serial Designation: B 46 – 27

These methods are issued under the fixed designation B 46; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1922; ADOPTED, 1923; REVISED, 1927.

GENERAL CONSIDERATIONS

Practically all of the following methods call for a preliminary separation of tin as meta-stannic acid by means of solution and digestion of the alloy in nitric acid. The meta-stannic acid so obtained is subject to contamination by such alloy constituents as copper and iron and will quantitatively contain such elements as phosphorus, arsenic and vanadium provided the ratio of tin to these elements in the alloy is high enough. In addition to the above drawbacks, tin is not always quantitatively precipitated as meta-stannic acid, particularly when the alloy contains more than 0.25 per cent of iron. In ordinary analyses of material containing but little iron, correction or provision is made for antimony and phosphorus when they are present, and the contaminants and the slight solubility losses are ignored. This procedure results in compensating errors in the determinations of copper and tin; for the impurities make up for dissolved tin while the dissolved tin plates out to a considerable extent with the copper. In umpire analyses, or with alloys high in iron or antimony, the above weaknesses of the method must be taken into account and provision must be made for the complete recovery of all tin, as well as the complete recovery of all contaminating elements carried down with the tin.

A special method is given for the determination of tin in alloys containing considerable phosphorus.

Methods are given for the determination of the impurities: sulfur and antimony.

[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee B-2 on Non-Ferrous Metals and Alloys.

DETERMINATION OF COPPER BY THE ELECTROLYTIC METHOD

APPARATUS FOR ELECTROLYSIS

Electrodes.—The electrodes recommended are of the stationary and not of the rotating type, as the stationary require less of the operator's time and there is less chance for erroneous results to be obtained than with the other kind. Rapid and accurate results are obtained with stationary electrodes made from platinum gauze.

Cathodes.—Platinum cathodes may be formed either from plain or perforated sheets, or from wire gauze, and may be either open or closed cylinders. They should give a depositing surface, counting both sides, of approximately 100 sq. cm. Gauze cathodes are recommended, and are best made from gauze containing approximately 400 meshes per sq. cm. (50 meshes per linear inch). The cathode should be stiffened by doubling the gauze for about 3 mm. at the top and at the bottom of the cylinder. The cylinder should be approximately 30 mm. in diameter and 30 mm. in height. The stem should be made from 1.14-mm. or 1.29-mm. wire, flattened and welded the entire width of the gauze; the height over all should be approximately 130 mm., and the gauze should be sand blasted.

Anodes.—Platinum anodes may be of the spiral type when used in the determination of copper by electrolysis, or in the electrolytic determination of lead when it is present in amounts not over 0.2 per cent. When used in the electrolytic determination of copper and lead together in samples containing 0.2 per cent of lead or over, the anodes should be of wire gauze. Spiral anodes should be made from 1.02-mm. or 1.14-mm. wire formed into a spiral of 7 turns having a height of approximately 51 mm. and a diameter of 16 mm., the length over all being approximately 145 mm. Platinum gauze used in making anodes should contain approximately 400 meshes per sq. cm. (50 meshes per linear inch). The gauze should be formed into closed cylinders approximately 12 mm. in diameter and 30 mm. in height. The cylinders should be stiffened by doubling the gauze for about 3 mm. at the top and at the bottom. The stem should be made from 1.02-mm. or 1.29-mm. wire, flattened and welded the entire width of the gauze; the height over all should be approximately 130 mm., and the gauze should be sand blasted.

METHOD

In a 150-cc. beaker, dissolve 1 g. of the bronze in 10 cc. of HNO_3 (sp. gr. 1.42). When the action has ceased, boil until the oxides of nitrogen are expelled, add 50 cc. of hot distilled water, and allow to stand and settle for about one hour, keeping the temperature just below the boiling point. Filter on double 7-cm. ashless papers, being careful to keep the solution hot throughout the process of filtration, and receiving the filtrate in a 200-cc. beaker of the tall type used in electrolysis. Wash with boiling hot water. Retain the papers containing the precipitate for subsequent use in the tin determination.

Add to the filtrate, 5 cc. of H_2SO_4 (sp. gr. 1.84), and determine copper by electrolysis, retaining the electrolyte, after the removal of the copper, for the subsequent determination of zinc. See the "Determination of Copper by the Electrolytic Method," Standard Methods of Chemical Analysis of Manganese Bronze (Serial Designation: B 27) of the American Society for Testing Materials.[1]

NOTES

Copper, zinc, and tin are conveniently determined on the same sample, tin being first removed, and any zinc tested for after copper has been deposited by electrolysis.

If the solution becomes cool during the first filtration, some of the meta-stannic acid (H_2SnO_3) may dissolve.

DETERMINATION OF TIN

(FOR SAMPLES FREE FROM PHOSPHORUS)

METHOD

See the "Determination of Copper by the Electrolytic Method."[2]

Use the papers containing the meta-stannic acid which was filtered off in the "Determination of Copper by the Electrolytic Method."[2] Ignite the papers with the precipitate while moist in a porcelain or platinum crucible, slowly at first, and finally at the full heat of the burner. If the precipitate weighs more than 20 mg., heat to constant weight, using a blast lamp. Weigh as SnO_2, and calculate to Sn.

NOTES

1. This method is not accurate for alloys which contain phosphorus, or which contain over 0.25 per cent of iron.

2. The ignited tin oxide contains small amounts of iron and copper as well as any phosphorus, antimony or arsenic which may be present in the alloy. Qualitative tests should be made for phosphorus, antimony and arsenic. In the absence of antimony and arsenic the following "Qualitative Test for Phosphorus" is here made use of to detect phosphorus and to estimate its amount, if any is found.

[1] See p. 700.

[2] See p. 739.

QUALITATIVE TEST FOR PHOSPHORUS

SOLUTIONS REQUIRED

Ferric Chloride.—Dissolve 25 g. of ferric chloride in 100 cc. of distilled water, and add 25 cc. of HCl (sp. gr. 1.19).

METHOD

Dip a piece of the alloy into a few cubic centimeters of ferric chloride for about ten seconds, and rinse it in running water. Alloys containing phosphorus are darkened noticeably where they have been dipped; alloys containing over 0.25 per cent of phosphorus are rendered almost black by this test.

In alloys containing up to 0.20 per cent of phosphorus, a correction for its presence in the ignited tin oxide may be made according to the following empirical method. From the phosphorus content of the alloy, which has been determined on a separate sample, calculate the weight of P_2O_5 and subtract two-thirds of this weight from the weight of the ignited tin oxide containing phosphorus. The remainder is considered as pure SnO_2. The factor for converting phosphorus to $\frac{2}{3} \times P_2O_5$ is 152.6 per cent, or approximately $1\frac{1}{2}$ times the phosphorus content of the sample.

If the alloy contains over 0.20 per cent of phosphorus, a special method for the determination of tin should be used.

In alloys which contain over 0.25 per cent of iron, use the method for the "Determination of Tin" in the Standard Methods of Chemical Analysis of Manganese Bronze (Serial Designation: B 27) of the American Society for Testing Materials.[1]

DETERMINATION OF TIN
(FOR SAMPLES CONTAINING PHOSPHORUS)

SOLUTIONS REQUIRED

Yellow Ammonium Sulfide.—Saturate 150 cc. of NH_4OH (sp. gr. 0.90) with H_2S gas, and then add 50 cc. more of NH_4OH. Dissolve in this solution 3 or 4 g. of sulfur flour, and about 1 g. of NH_4Cl. Make up this solution fresh, and filter immediately before using.

Dilute Yellow Ammonium Sulfide for Washing.—Mix 20 cc. of yellow ammonium sulfide, prepared as above, and 400 cc. of distilled water.

Ammonium Acetate for Washing.—Dissolve 10 g. of ammonium acetate in 300 cc. of distilled water, make slightly acid with acetic acid and saturate with H_2S gas.

[1] See p. 706.

METHOD

See the "Determination of Copper by the Electrolytic Method."[1]

Use the papers containing the freshly filtered meta-stannic acid which was filtered off in the "Determination of Copper by the Electrolytic Method."[1] Transfer the papers with the precipitate to a 150-cc. beaker, and cover with 40 to 50 cc. of yellow ammonium sulfide. Warm for about 15 minutes, or until the meta-stannic acid has dissolved. Filter and wash thoroughly with dilute yellow ammonium sulfide. Acidify the combined filtrate and washings cautiously with 50-per-cent acetic acid. Warm, and allow the precipitated tin sulfide and sulfur to settle. Filter on double papers and wash with ammonium acetate solution. Dry the precipitate, and place it with the papers in a porcelain crucible which projects part way through a hole in a piece of asbestos board. Heat slowly until the free sulfur has been driven off, but without allowing the sulfur to burn. When the sulfur has been expelled, place the crucible on a triangle and ignite slowly at first, and finally at the full heat of the burner. If the precipitate weighs more than 20 mg., heat to constant weight, using a blast lamp. Weigh as SnO_2, and calculate to Sn.

Accuracy.—Duplicate determinations should check within 0.06 per cent of tin.

NOTES

1. The ignited tin oxide will contain any arsenic or antimony that was present in the sample.

2. During the ignition, if the sulfur is allowed to burn, some tin sulfate may be formed, causing high results. On the other hand, low results may be caused by too high heat, which causes spattering and volatilizes some tin sulfide.

DETERMINATION OF LEAD
BY THE
ELECTROLYTIC METHOD

APPARATUS

Electrodes and other apparatus used in electrolysis; see the "Determination of Copper by the Electrolytic Method."[1]

METHOD

In a 150-cc. beaker, dissolve 1 g. of the bronze in 10 cc. of HNO_3 (sp. gr. 1.42). When the action has ceased, boil until the oxides of nitrogen are expelled; add 50 cc. of boiling hot distilled water and allow to stand and settle for about one hour, keeping the temperature just below the boiling point. Filter on double 7-cm. ashless papers, being careful to keep the solution hot throughout the process of

[1] See p. 739.

filtration. Wash with boiling hot water. Add to the filtrate 9 cc. of HNO_3 (sp. gr. 1.42) and dilute to about 150 cc. with distilled water. Insert a sand-blasted platinum gauze electrode in the anode terminal; this electrode may be one of the type used as cathode in the "Determination of Copper by the Electrolytic Method,"[1] or it may be one of the sand-blasted gauze anodes therein described. Insert in the cathode terminal one of the electrodes used as anode in the "Determination of Copper by the Electrolytic Method." Cover with a pair of split watch glasses and electrolyze. For each solution use a current of 2 amperes at 10 volts continued for about 2 hours. Wash down the cover glasses, electrodes, and sides of the beakers, raising the level of the liquid 5 or 6 mm., and continue the electrolysis for 15 minutes. If no darkening of the newly exposed surface of the platinum can be detected, the lead has been entirely deposited. If the newly exposed surface of the platinum is darkened, continue the electrolysis until no such darkening can be detected when the current has been continued for 15 minutes after the level of the liquid has been raised.

When the lead has been entirely deposited, remove the anode quickly and rinse it in distilled water and then in alcohol, and dry in an oven at 210° C. for 30 minutes. Weigh as PbO_2, using the factor for lead 0.8643 instead of the theoretical value.

NOTES

1. It is impossible to remove the tin quantitatively as H_2SnO_3 in the case of alloys containing over 0.25 per cent of iron, and traces of tin are sometimes found in the PbO_2 deposit.

2. In this and in the following method, a slight amount of lead may be retained by the H_2SnO_3. This should be recovered in very accurate work, but is neglected in a routine analysis.

3. *Samples for Analysis.*—When lead is less than 0.10 per cent, a 5 or 10-g. sample is taken. The 5-g. sample should be dissolved in 25 cc. of HNO_3. The 10-g. sample should be dissolved in 45 cc. of HNO_3. When the lead content is greater than 15 per cent, dissolve the sample in HNO_3 as described under Method, transfer the solution to a graduated flask and choose aliquot portions for analysis in order not to exceed the above mentioned limit of lead to be deposited on the anode as PbO_2. The lead peroxide will tend to flake off the electrode when the amount deposited becomes excessive.

DETERMINATION OF LEAD AS SULFATE (OPTIONAL)

SOLUTIONS REQUIRED

"*Lead-Acid.*"—Mix 300 cc. of H_2SO_4 (sp. gr. 1.84) and 1800 cc. of distilled water. Dissolve 1 g. of lead acetate, c. p., in 300 cc. of

[1] See p. 739.

distilled water and add this to the hot solution with stirring. Let stand at least 24 hours, and siphon through a thick asbestos filter.

Dilute Alcohol for Washing.—Mix equal parts of denatured alcohol and distilled water.

METHOD

In a 150-cc. beaker, dissolve 1 g. of the bronze in 10 cc. of HNO_3 (sp. gr. 1.42). When the action has ceased, boil until the oxides of nitrogen are expelled, add 50 cc. of boiling hot distilled water, and allow to stand and settle for about one hour, keeping the temperature just below the boiling point. Filter on double 7-cm. ashless papers, being careful to keep the solution hot throughout the process of filtration. Wash with boiling hot water. Add 40 cc. of lead-acid and evaporate until copious fumes of H_2SO_4 are evolved. Cool, add 35 cc. of distilled water to dissolve the salts. Heat to boiling and allow to cool and settle for 5 hours, or over night, if convenient. Filter on a weighed Gooch crucible and wash with lead-acid. Wash out the lead-acid with dilute alcohol, set the Gooch crucible inside a porcelain crucible, ignite for five minutes at the full heat of a Tirrell burner, cool and weigh as $PbSO_4$, and calculate to Pb.

NOTES

1. Copper and lead may be determined on the same samples if so desired. In such a case, after filtering off the lead sulfate and washing with lead-acid, and before washing with dilute alcohol, remove the filtrate, add 3 cc. of HNO_3 (sp. gr. 1.42), dilute to 120 cc. and determine copper by electrolysis. See the "Determination of Copper by the Electrolytic Method."[1]

2. Copper and lead may also be determined simultaneously by the electrolytic method. See the Standard Methods of Chemical Analysis of Manganese Bronze (Serial Designation: B 27) of the American Society for Testing Materials.[2]

DETERMINATION OF IRON

SOLUTIONS REQUIRED

Yellow Ammonium Sulfide.—Saturate 150 cc. of NH_4OH (sp. gr. 0.90) with hydrogen sulfide gas, and then add 50 cc. more of NH_4OH. Dissolve in this solution 3 or 4 g. of sulfur flour, and about 1 g. of NH_4Cl. Make up this solution fresh, and filter it immediately before use.

Dilute Yellow Ammonium Sulfide for Washing.—Mix 20 cc. of yellow ammonium sulfide, prepared as above, and 400 cc. of distilled water.

Other Solutions.—See the "Determination of Iron" in the Standard Methods of Chemical Analysis of Brass Ingots and Sand Castings

[1] See p. 739. [2] See p. 700.

(Serial Designation: B 45) of the American Society for Testing Materials.[1]

METHOD

In a 150-cc. beaker, dissolve 1 g. of bronze in 10 cc. of HNO_3 (sp. gr. 1.42). When the action has ceased, boil until the oxides of nitrogen are expelled, add 50 cc. of boiling water, and allow to stand and settle for about one hour, keeping the temperature just below the boiling point. Filter on double 7-cm. papers, keeping the solution hot, and wash with boiling hot water. Retain both the filtrate and the precipitate. Transfer the papers with the precipitate to a 150-cc. beaker, and cover them with 40 to 50 cc. of yellow ammonium sulfide. Warm about 15 minutes, or until the meta-stannic acid is dissolved. Filter and wash thoroughly with hot, dilute yellow ammonium sulfide.

Dissolve the small black residue on the filter with hot dilute HCl, receiving the solution in a small beaker. Add 5 cc. of HNO_3 (sp. gr. 1.42) and boil to oxidize sulfur and iron. Add this small solution to the original filtrate from the meta-stannic acid. Add about 5 g. of NH_4Cl, then NH_4OH (sp. gr. 0.90) and proceed as in the "Determination of Iron" in the Standard Methods of Chemical Analysis of Brass Ingots and Sand Castings (Serial Designation: B 45) of the American Society for Testing Materials.[1]

DETERMINATION OF NICKEL BY THE DIMETHYLGLYOXIME METHOD

SOLUTIONS REQUIRED

Dimethylglyoxime Solution.—Dissolve 5 g. of dimethylglyoxime in 500 cc. of grain alcohol, and filter before using.

Sodium Potassium Tartrate Solution.—Dissolve 200 g. of the salt in 1 liter of distilled water.

Dilute Ammonia for Washing.—Solution containing 10 cc. of NH_4OH (sp. gr. 0.90) per liter of water.

METHOD

In a 200-cc. electrolytic beaker, dissolve a 1-g. sample exactly as in the "Determination of Copper by the Electrolytic Method"[2] and remove the copper by electrolysis. Evaporate the solution to about 100 cc., filter, add about 1 g. of NH_4Cl, then 10 cc. of sodium potassium tartrate solution, and nearly neutralize with NH_4OH (sp. gr. 0.90).

[1] See p. 731.
[2] See p. 739.

Heat nearly to boiling, add 5 cc. of dimethylglyoxime solution for each 0.01 g. or fraction of nickel present and then NH_4OH in slight excess. Let stand at least 30 minutes on the steam bath, filter and wash with dilute ammonia solution. For accurate work, the precipitate should be dissolved in hot HCl (1 : 1) and reprecipitated as before. Filter on a weighed Gooch crucible, wash with dilute ammonia solution, and then with hot water; dry at 110 to 120° C. for about two hours and weigh as the glyoxime salt which contains 20.31 per cent of nickel. If it is preferred, instead of by weighing the glyoxime salt, the nickel can be determined electrolytically as follows: Dissolve the red precipitate of nickel glyoxime in hot HCl (1 : 1), add 10 cc. of H_2SO_4 (1 : 1) and evaporate to strong fumes. Dilute, neutralize with NH_4OH (sp. gr. 0.90), and add 20 cc. in excess. The final volume should be about 150 cc. Electrolyze with a current of 0.3 ampere per solution. Test the solution for completion of deposition with fresh H_2S water as is done in the "Determination of Copper by the Electrolytic Method."[1] Remove the cathode, wash with water and dry with alcohol as in the "Determination of Copper by the Electrolytic Method." Weigh the deposit as metallic nickel.

DETERMINATION OF ZINC

METHOD

See the "Determination of Copper by the Electrolytic Method."[1]

After the copper has been completely deposited by electrolysis, quickly remove the cathode and wash it thoroughly with distilled water, catching the washing in the beaker containing the electrolyte. Heat the solution and saturate with H_2S gas. Filter off any precipitate, and boil the solution to expel H_2S. Make the solution barely alkaline with NH_4OH, and add 25 cc. of 85-per-cent formic acid. Dilute the solution with distilled water to 300 cc., heat to boiling, and saturate with H_2S gas. Filter, wash with hot water and dissolve the precipitate with hot HCl (1 : 1) and transfer the solution to a weighed platinum or porcelain dish or crucible. Add a few drops of H_2SO_4 (sp. gr. 1.84) and evaporate the solution until copious fumes escape. If the solution is not clear and colorless, cool, add a few cubic centimeters of HNO_3 (sp. gr. 1.42) and again evaporate the solution until fumes of H_2SO_4 come off freely. Repeat the treatment with HNO_3, if necessary, until the organic matter is destroyed, and the solution is colorless. Remove the excess of H_2SO_4 by heating the dish cautiously, and finally heat to dull redness. Weigh as $ZnSO_4$ and calculate to Zn.

[1] See p. 739.

DETERMINATION OF PHOSPHORUS BY THE ALKALIMETRIC METHOD

SOLUTIONS REQUIRED

Nitric Acid for Dissolving.—Mix 1000 cc. of HNO_3 (sp. gr. 1.42) and 1200 cc. of distilled water.

Nitric Acid for Washing.—Mix 20 cc. of HNO_3 (sp. gr. 1.42) and 1000 cc. of distilled water.

Ammonium Molybdate Solution No. 1.—Place in a beaker 100 g. of 85-per-cent molybdic acid, mix it thoroughly with 240 cc. of distilled water, add 140 cc. of NH_4OH (sp. gr. 0.90), filter and add 60 cc. of HNO_3 (sp. gr. 1.42).

Ammonium Molybdate Solution No. 2.—Mix 400 cc. of HNO_3 (sp. gr. 1.42) and 960 cc. of distilled water.

When the solutions are cold, add solution No. 1 to solution No. 2, stirring constantly; then add 0.1 g. of ammonium phosphate dissolved in 10 cc. of distilled water and let stand at least 24 hours before using.

Potassium Nitrate, 1-per-cent Solution.—Dissolve 10 g. of potassium nitrate in 1000 cc. of distilled water.

Phenolphthalein Indicator.—Dissolve 0.2 g. in 50 cc. of 95-per-cent ethyl alcohol and 50 cc. of distilled water.

Standard Sodium Hydroxide.—Dissolve 3.3 g. of purified NaOH in 1000 cc. of distilled water, add a slight excess of 1-per-cent solution of barium hydroxide, let stand for 24 hours, decant the liquid, and standardize it against a steel of known phosphorus content as determined by the molybdate-magnesia method, so that 1 cc. will be equivalent to 0.01 per cent of phosphorus on the basis of a 1-g. sample (see Notes). Protect the solution from carbon dioxide with a soda-lime tube.

Ferric Chloride.—Dissolve 100 g. of ferric chloride (phosphorus free) in 100 cc. of distilled water.

Standard Nitric Acid.—Mix 5 cc. of HNO_3 (sp. gr. 1.42) and 1000 cc. of distilled water. Titrate the solution against standardized NaOH, using phenolphthalein as indicator, and make it equivalent to the sodium hydroxide by adding distilled water.

METHOD

In a 400-cc. beaker, dissolve a 1-g. sample in 10 cc. of HNO_3 (sp. gr. 1.42) and heat until brown fumes are driven off; then add 15 cc. of HCl (sp. gr. 1.19) and evaporate to dryness. Add 10 cc. of HCl (sp. gr. 1.19) and again evaporate to dryness, but do not bake.

Add 15 cc. of HCl (sp. gr. 1.19) and heat to solution; dilute with 50 cc. of distilled water and bring to a boil. Take off the hot plate and wash down the cover glass and sides of the beaker, add 20-mesh c. p. zinc, 2 or 3 g. at a time until the solution becomes colorless, that is until all the copper, tin and lead are precipitated. Filter, receiving the filtrate in a 400-cc. beaker, and wash well with hot water.

Add 3 cc. of the ferric chloride solution to this filtrate and make faintly ammoniacal; bring to a boil, let settle and filter. Dissolve this precipitate in hot dilute HCl and again make ammoniacal; heat to boiling, let settle and filter, washing well with hot water.

Dissolve this precipitate in as small a quantity of hot dilute HNO_3 as possible, receiving the solution in a 300-cc. Erlenmeyer flask; wash filter free of iron with hot dilute HNO_3 and hot distilled water. Evaporate to about 15 cc., cool, make ammoniacal, then neutralize with HNO_3 (sp. gr. 1.42) and add 5 cc. in excess. Cool to 80° C., and add 60 cc. of the ammonium molybdate solution. Let stand one minute, then shake three minutes and let settle. Filter on an 11-cm. filter (using a small quantity of paper pulp on the filter) and wash free of iron with 2-per-cent nitric acid wash, then free of acid with the 1-per-cent potassium nitrate solution.

Place the paper in the thoroughly washed acid-free flask in which the original precipitation was made, add 25 cc. of distilled water and an excess of the standard sodium hydroxide solution. By using a long glass rod, the paper can be pulped and the yellow precipitate dissolved in a very few seconds. Wash off the rod and the sides of the flask and add a few drops of the phenolphthalein solution and titrate the excess of standard NaOH with the standard HNO_3. The strength of the standard NaOH and the standard HNO_3 in terms of phosphorus can be determined by using a standard steel or preferably a standard phosphor bronze in which the phosphorus has been determined by the molybdate-magnesia method.

Accuracy.—Duplicate determinations should check within 0.01 per cent of phosphorus.

NOTES

1. The ammonium molybdate solution should be kept in a cool place and should always be filtered before using.

2. All distilled water used in titration should be freed from carbon dioxide by boiling or otherwise.

3. Bureau of Standards Standard Steel No. 19 (*a*) or a bronze of known phosphorus content are recommended as suitable materials for standardization of the sodium hydroxide solution.

4. (Gravimetric method, optional.) It is considered by some that more accurate

results can be obtained by a gravimetric determination of phosphorus as $Mg_2P_2O_7$. This can be carried out by dissolving the yellow molybdate precipitate in 20 cc. of NH_4OH (1 : 1) to which has been added 2 g. of citric acid, precipitating with magnesia mixture, and proceeding as usual, finally weighing as $Mg_2P_2O_7$.

5. Determination of phosphorus by the ferric alum method is optional. See the Standard Methods of Chemical Analysis of Gun Metal (Serial Designation: B 28) of the American Society for Testing Materials.[1]

DETERMINATION OF ANTIMONY BY THE VOLUMETRIC METHOD

SOLUTIONS REQUIRED

Potassium Permanganate.—Dissolve 0.3 g. of potassium permanganate in 1000 cc. of distilled water. Standardize by dissolving 25 mg. of pure antimony in 15 cc. of boiling H_2SO_4 and proceeding according to the method from this point.

METHOD

In a 250-cc. beaker, dissolve 5 g. of bronze in 25 cc. of HNO_3 (sp. gr. 1.42). When the action has ceased, boil until the oxides of nitrogen are expelled, add 125 cc. of boiling water and allow to stand and settle for one hour or longer, keeping the temperature just below the boiling point. Filter on double 9-cm. closely woven papers, keeping the solution hot. Wash with boiling water. Discard the filtrate.

Transfer the papers containing the tin and antimony to a 350-cc. Erlenmeyer flask and add 25 cc. of HNO_3 (sp. gr. 1.42), 5 g. of ammonium persulfate, and 15 cc. of H_2SO_4 (sp. gr. 1.84). Boil to strong fumes of SO_3. If the solution is brown, *cool* and add 5 cc. of HNO_3 (sp. gr. 1.42) and a little more (1 g. or less) persulfate, if necessary, and boil again to strong fumes of SO_3. When the solution is colorless, cool, add 20 cc. of distilled water, 20 cc. of HCl (sp. gr. 1.19) and 1 g. of sodium sulfite. Boil gently for 10 minutes to expel SO_2 completely. Dilute with 200 cc. of distilled water and cool to 10 to 12° C. in ice or under running water.

Titrate with standard permanganate solution until the appearance of a decided permanent pink color.

NOTES

1. In alloys containing a large excess of tin, the antimony is precipitated quantitatively with the meta-stannic acid.

[1] See p. 711.

2. Ammonium persulfate and HNO_3 are used to destroy the filter paper, and subsequent boiling with H_2SO_4 effects the solution of the tin and antimony. A mixture of fuming HNO_3 and H_2SO_4 might be used to accomplish the same results, but the persulfate mixture is much more efficient.

3. If the solution becomes cool during the first filtration, some of the meta-stannic acid may dissolve.

4. If arsenic is present, correction should be made for it.

DETERMINATION OF SULFUR

METHOD

Weigh out four 5-g. samples of bronze into 250-cc. beakers. Dissolve each in 25 cc. of HNO_3 (sp. gr. 1.42) and boil until the disappearance of red fumes. Add 125 cc. of boiling water and allow to settle for one hour or longer, keeping the temperature just below the boiling point. Filter on double 12.5-cm. closely woven papers, keeping the solution hot. Wash with boiling water. Discard the meta-stannic acid precipitates, combine the four filtrates in a tall 700-cc. beaker and add 0.5 g. of sodium carbonate, and evaporate the solution until syrupy. Cool somewhat, then dilute to the lip with warm water. There should be present a layer about 6 mm. in thickness, composed of basic salts of copper. Electrolyze, using large stationary electrodes, at a current of 4 amperes, or using the Frary solenoid at a current of about 10 amperes. The lead must be removed at the anode as the copper is taken out at the cathode. When copper and lead are out, evaporate the electrolyte to small volume, cover the beaker, add 75 cc. of HCl (sp. gr. 1.19) and boil down to small volume. Add 75 cc. more HCl and evaporate to dryness to dehydrate any silica present. Moisten with about 0.5 cc. of HCl and take up with 20 cc. of hot water. Filter into a small beaker. Heat the filtrate to boiling and add 10 cc. of 5-per-cent $BaCl_2$ solution, drop by drop, with stirring. Allow to settle at least five hours, filter on a small ashless paper, and wash with hot water. Ignite cautiously in a small porcelain or platinum crucible, and then heat to a bright redness for 20 minutes. Cool and weigh the $BaSO_4$ and calculate to sulfur.

NOTES

1. Throughout the entire analysis, the utmost precautions must be taken to prevent contamination by sulfur in any form, H_2SO_4 fumes, H_2S, and SO_2 gases especially. All heating with gas burners must be avoided. Run a blank with each analysis, adding all the reagents and subjecting it to the same operations as the beakers containing the drillings. Subtract the amount of $BaSO_4$ found in the blank from that in the determinations. If this blank amounts to 0.002 g., it is a sign of poor work or impure reagents and the analysis should be repeated. Wash out all beakers, funnels, etc., with distilled water before using.

2. It is necessary to keep the solution containing the meta-stannic acid hot during filtration. If the solution becomes cool, some of the meta-stannic acid may dissolve.

DETERMINATION OF ARSENIC

SOLUTIONS REQUIRED

Ammonium Carbonate.—Dissolve 150 g. of ammonium carbonate in one liter of distilled water.

METHOD

Dissolve the sample (5.00 to 10.00 g.) in a 100-cc. beaker in 10 cc. of HNO_3 (sp. gr. 1.42) and 30 cc. of HCl (sp. gr. 1.19). When solution is complete, cool, add 35 cc. of H_2SO_4 (sp. gr. 1.84) evaporate to the appearance of copious fumes of H_2SO_4, and continue the fuming for from ten to fifteen minutes. Cool, take up in HCl (sp. gr. 1.19), transfer to an 800-cc. flask having a two-hole stopper with separatory funnel and outlet tube connecting with a vertical condenser outside. (The part of the outlet tube within the distilling flask should have a steam outlet hole about 1 cm. from the open end.) Rinse the beaker with HCl (sp. gr. 1.19) and dilute the solution with the acid to make a total volume of 350 to 450 cc. Add 10 g. of cuprous chloride (Cu_2Cl_2), connect the flask with the condenser, and gradually raise the contents of the flask to boiling. Catch the distillate in a tall 400-cc. beaker containing 100 cc. of cold water. The end of the condenser should extend several millimeters into the water in the beaker and the beaker should be surrounded with ice water in order to avoid any possible volatilization of arsenious chloride. After about 100 cc. of distillate has passed over, remove the flame from the distilling flask, pour 3 to 5 cc. of hypophosphorus acid through the separatory funnel into the distilling flask, and redistill as before, catching the distillate in the same beaker. The volume of the second distillate should be 50 to 100 cc. Pass a rapid current of H_2S through the distillate for one hour, allow to settle, and filter on a weighed Gooch crucible. Wash twice with HCl (1 : 1), four times with cold water, three times with alcohol, and four times with CS_2. Dry at 110° C. for 10 minutes, and weigh after cooling. Dissolve the As_2S_3 with $(NH_4)_2CO_3$ solution, wash thoroughly with water, dry for 30 minutes at 110° C. and reweigh after cooling. The difference in weights multiplied by 0.609 gives the weight of arsenic.

NOTE

1. Blank determinations should be made on the reagents carried along as in the method and the proper corrections made.

DETERMINATION OF ALUMINUM IN SMALL QUANTITIES

(*a*) *General Method for Accurate Work*

SOLUTIONS REQUIRED

"*Electrolytic Solution.*"—Mix 300 cc. of HNO_3 (sp. gr. 1.42), 1700 cc. of distilled water, and 500 cc. of H_2SO_4 (sp. gr. 1.84).

Acidified H_2S Water for Washing.—Dilute 10 cc. of HCl (sp. gr. 1.19) with 1000 cc. of distilled water and saturate with H_2S.

Phenylhydrazine Solution for Washing.—Add saturated SO_2 water to a few cubic centimeters of phenylhydrazine until the crystallin sulfite first formed is redissolved, and then add phenylhydrazine, drop by drop, with vigorous agitation, until the odor of SO_2 is no longer perceptible; dilute 5 to 10 cc. of this solution with 100 cc. of hot water and allow to remain at the boiling point for a few minutes so as to get rid of the excess SO_2.

NH_4Cl Solution for Washing (2-per-cent).—Mix 30 cc. of HCl (sp. gr. 1.19) with 200 cc. of distilled water, add methyl red, neutralize with NH_4OH until the solution changes to a distinct yellow, and then dilute to 1000 cc. with water.

METHOD

Dissolve 1 g. of brass or bronze in 35 cc. of "electrolytic solution," dilute with 100 cc. of distilled water and remove copper by electrolysis. Evaporate the electrolyte to fumes of SO_3. (If much tin is present, boil the sulfuric acid solution vigorously for a few minutes.) Cool, and dilute with 100 cc. of water. Filter off $PbSO_4$ and any tin which may be precipitated at this point, washing with hot water. Dilute the filtrate to at least 200 cc.

Pass H_2S into the filtrate for 30 minutes. This will precipitate any copper, lead, tin, arsenic, or antimony which may be present. Allow the sulfides to settle, and filter, washing with acidified H_2S water. Boil the filtrate to one-half volume to expel H_2S, add 3 cc. HNO_3 (sp. gr. 1.42) and boil for a few minutes to oxidize iron.

Precipitate iron and aluminum according to the following:[1] Add 10 cc. of HCl (sp. gr. 1.19) and just neutralize with NH_4OH, using methyl red as an indicator. Boil for two minutes and filter, washing with hot NH_4Cl (2-per-cent). Dissolve the precipitate from the paper with *boiling hot* HCl (1:1) and wash alternately with hot water and HCl (1:1) into the beaker in which the precipitation was made. Re-

[1] Blum: U. S. Bureau of Standards *Scientific Paper, No. 268*, 1916; *Journal*, American Chemical Society, Vol. 38, p. 1282 (1916).

precipitate the iron and aluminum following the same procedure as before.

Dissolve the precipitate again with hot HCl (1:1), dilute to 100 cc. with water, make just ammoniacal, then only acid enough to hold iron in solution. Add sufficient saturated solution of ammonium bisulfite to reduce the iron (5 to 20 drops). Add a few drops of methyl orange, quickly bring to neutrality with NH_4OH, and then add 6 to 7 drops of HCl (1:1) in excess. Finally, add from 1 to 3 cc. of phenylhydrazine and stir until the precipitate becomes flaky. The supernatant liquid should be plainly acid to litmus and the precipitate may be colored owing to organic matter. Filter and wash with phenylhydrazine wash solution. Ignite in a weighed platinum crucible, finishing with the blast for 5 minutes. Weigh as Al_2O_3. The weighing should be made rapidly and with the crucible covered as Al_2O_3 is somewhat hygroscopic.

NOTES

1. For small amounts of aluminum, a 5-g. sample should be used. In this case dissolve in 60 cc. of "assay solution" of the following proportions:

7 volumes HNO_3 (sp. gr. 1.42);
10 volumes H_2SO_4 (sp. gr. 1.84);
25 volumes H_2O.

2. When phosphorus is present the final precipitate will be $Al_2O_3+P_2O_5$. In this case it is necessary to fuse the residue with Na_2CO_3, dissolve with hot water, acidify with HNO_3, and determine phosphorus in accordance with the Determination of Phosphorus by the Alkalimetric Method.[1] The phosphorus is calculated to P_2O_5 and subtracted.

3. For accurate work the Al_2O_3 residue is treated with HF and H_2SO_4 for the removal of possible SiO_2.

4. Ammonium bisulfite solution may be prepared by saturating cold NH_4OH (1:1) with SO_2 until yellow.

5. This method is especially satisfactory for small amounts of aluminum in brass or bronze since no reagents are used which may contaminate the precipitate with aluminum, iron or silica. A precipitate with phenylhydrazine gives positive indication of the presence of aluminum.

(*b*) *Rapid Method for Control Work*

SOLUTIONS REQUIRED

Sodium Hydroxide Solution (*2.5-per-cent*).—Dissolve 25 g. of NaOH (free from aluminum) in water and dilute to 1000 cc.

Sodium Sulfide Solution.—Dissolve 150 g. of NaOH (free from aluminum) in 1000 cc. of water, saturate 500 cc. of this solution with hydrogen sulfide, and mix with the remaining 500 cc. of solution.

[1] See p. 747.

Dilute Hydrochloric Acid (1:3).—Mix 200 cc. of HCl (sp. gr. 1.19) with 600 cc. of water.

Acidified Hydrogen Sulfide Water.—Dilute 10 cc. of HCl (sp. gr. 1.19) with 1000 cc. of water and saturate the solution with hydrogen sulfide.

Ammonium Chloride Solution (2-per-cent).—Mix 30 cc. of HCl (sp. gr. 1.19) with 200 cc. of water, add methyl red, neutralize with ammonia until the solution changes to a distinct yellow, and then dilute to 1000 cc. with water.

METHOD

Dissolve 2 g. of the sample in 20 cc. of HCl (sp. gr. 1.19) and 5 cc. of HNO_3 (sp. gr. 1.42). Boil the solution to expel chlorine, and dilute with 50 cc. of water. Nearly neutralize the cold solution with NaOH solution (2.5-per-cent, or stronger if much free acid is present), and pour it slowly and with constant shaking into a 500-cc. volumetric flask containing 100 cc. of sodium sulfide solution. Dilute to the mark with NaOH solution (2.5-per-cent) and mix thoroughly. Filter on a large, dry, No. 42 Whatman filter paper (or its equivalent) and keep the paper well filled with the solution lest iron be oxidized and dissolved. Reject the first 20 to 25 cc., and catch exactly 250 cc. which will represent 1 g. of sample. In routine analyses of material containing not more than 1 per cent of aluminum, the aliquot portion can be gathered in a 250-cc. graduate.

Transfer the aliquot portion to a 600-cc. beaker, neutralize the solution with dilute HCl (1:3), and finally add 25 cc. in excess. Digest at 40 to 60° C. for 1 hour, filter, and wash the paper and precipitate with acidified H_2S water.

Boil the filtrate and washings to expel H_2S, add a few drops of methyl red indicator, and then dilute ammonia (1:2) until the solution is just distinctly yellow. Boil for 1 to 2 minutes and filter at once through a small filter. Wash the beaker, paper, and precipitate two or three times with hot NH_4Cl solution (2-per-cent) and discard the filtrate. Dissolve the precipitate in 200 cc. of hot dilute HCl (1:3), wash the filter thoroughly with small portions of hot water, and reserve it for the second filtration. Dilute the filtrate to 50 cc., add methyl red, and precipitate with dilute ammonia (1:2) as before. Filter, wash with hot NH_4Cl solution (2-per-cent), ignite, and weigh.

The ignited residue is prone to carry silica and must be purified before weighing as follows: Add one or two drops of water, one drop of diluted H_2SO_4, and 1 to 5 cc. of HF. Evaporate to dryness, increase

the heat slowly, and finally heat with a blast lamp or its equivalent. Weigh as Al_2O_3. The weight of Al_2O_3 corrected for the blank and multiplied by 52.94 gives the percentage of aluminum.

NOTES

The first aluminum hydroxide precipitate will carry down some NaCl and much of any silica that was dissolved in the NaOH solution; hence, it is not safe to omit the second precipitation and the HF treatment. There is no attack on the glassware during the short contact with the weak, cool, alkaline solution. It is, of course, preferable that the NaOH be free from aluminum. The most satisfactory test for it lies in running an analysis with non-ferrous alloys containing no aluminum. Direct test, by acidification followed by precipitation with ammonia, is sufficient if no precipitate is obtained, but is of doubtful value in case one appears, for it may contain other elements, such as iron, which do not affect the results.

If phosphorus is known to be present, the method should be followed through the first addition of ammonia. If aluminum is indicated, re-acidify the solution with HCl, add macerated paper, two drops of methyl orange, and 10 cc. of a solution of diammonium phosphate (10-per-cent). Render the solution just ammoniacal, then just restore the pink color with dilute HCl (1: 3), heat to boiling, and add 30 cc. of a solution of ammonium acetate (25-per-cent). Boil for 5 minutes, filter on an 11-cm. No. 42 Whatman or similar filter paper, and wash with hot NH_4NO_3 solution (5-per-cent) until 5 cc. of the washings no longer give a test for chlorides with acidified $AgNO_3$. Ignite in platinum or porcelain, heat at approximately 1100° C. for 10 minutes, and weigh as $AlPO_4$. This method is not strictly accurate on account of the uncertain composition of the phosphate, but is sufficiently accurate for all but the most painstaking analyses.

STANDARD METHODS
OF
METALLOGRAPHIC TESTING OF IRON AND STEEL[1]

Serial Designation: E 3 – 24

These methods are issued under the fixed designation E 3; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1921; ADOPTED IN AMENDED FORM, 1924.

MACROSCOPIC EXAMINATION.

PREPARATION OF SURFACE.

In order to show up both chemical and crystallin heterogeneity, sections of iron and steel are more or less deeply etched in order to bring out their macrostructure. In this way the persistence of the dendritic structure of castings even after much heat treatment and mechanical working, physical unsoundness such as blowholes, gas cavities, porosity, fine internal cracks and flakes, discontinuities of structure such as found in welding, flow of metal as in riveting, punching, hot pressing and forging, etc., are brought out.

Suitable sections are cut, smoothed and then ground on various grades of emery paper in order to obtain a smooth flat surface. In some cases it is necessary to continue polishing through No. 0 and No. 00 French Emery Papers. The sample ought to have a surface free from grease and dirt; if necessary it is then freed from all grease by cleaning with gasoline and then alcohol when it is ready for immersion in the solution.[2]

SOLUTIONS USED IN ETCHING.

Macroscopic etching of iron and steel was used as early as 1783 by Bergman. Many different solutions have been used and many of them are given by Campbell,[3] and more recently by Rawdon.[4]

Of the following solutions 1 (*a*) and 2 are recommended.

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[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee E-4 on Metallography.

[2] For large sections various methods have been devised depending on the material. Surface grinding when carefully done gives excellent results.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. XV, Part II, p. 96 (1915).

[4] "Structure and Related Properties of Metals," Bureau of Standards *Circular No. 113.*

1. To show up segregation and the like:

(*a*) Hot concentrated hydrochloric acid used at about 100° C. A deep etched specimen may be printed with printer's ink.

(*b*) Etching for 4 to 5 hours with 5-per-cent picric acid in alcohol.

2. To show up variations in crystallin structure as well as segregation:

One to two grams of ammonium persulfate in 10 cc. of water. This is probably the best reagent for developing this phase of the structure in iron and steel.[1]

3. To show up the distribution of phosphorus:

Various reagents containing copper chloride are used. The copper coats those portions which are low in phosphorus and leaves the high phosphorus areas bright. It has recently been shown that nickel and other alloys give similar effects, also that oxide of iron acts in the same way. The accompanying list shows the various solutions which have been recommended:

Heyn.—Copper-ammonium chloride ..... 10 g.
Water ..... 100 cc.

A somewhat weaker solution is better, the specimen being etched two or three times in fresh solution if necessary. The liquid is gently agitated. The coating of spongy copper forming on the face of the specimen is easily removed with a swab of wet cotton. Portions high in carbon, sulfur and phosphorus will have darkened. If the copper film adheres, a 0.5-per-cent solution of ammonium persulfate will facilitate its removal.

Stead.—$CuCl_2$ ..... 10 g.
$MgCl_2$ ..... 40 g.
HCl ..... 10 cc.
H_2O ..... 20 cc.
Alcohol to ..... 1000 cc.

Dissolve salts in smallest possible amount of hot water and make up to 1000 cc. with absolute alcohol.

For small specimens the reagent is applied drop by drop until structure is developed. The specimen is then washed with boiling water and then alcohol.

Another method is to wash off the deposited copper with ammonia and so increase the contrast.

Le Chatelier and Lemoine.—$CuCl_2$ ..... 10 g.
$MgCl_2$ ..... 40 g.
HCl ..... 20 cc.
H_2O ..... 180 cc.
Alcohol ..... 1000 cc.

[1] Rawdon, "Macro-etching with Ammonium Persulphate," *Scientific Paper No. 403*, Bureau of Standards (1920).

Applied like Stead's reagent. Contrast can be increased by electrolysis, using a single battery cell, keeping the current below 50 milliamperes.

Rosenhain and Haughton.—

Fe_2Cl_6	30 g.
HCl	100 cc.
$CuCl_2$	10 g.
$SnCl_2$	0.5 g.
H_2O	1000 cc.

The copper adheres firmly. Pearlite areas remain bright. Ferrite darkened by deposited copper, the purest parts darkening the fastest. Pitting can be avoided by diluting the reagent.

LeChatelier and Dupuy.—

Ethyl alcohol	100 cc.
H_2O	10 cc.
$CuCl_2$	1 g.
Picric acid	0.5 g.
HCl (concentrated)	1.3 to 2.5 cc., varying with material.

Oberhoffer.—

Ethyl Alcohol	500 cc.
H_2O	500 cc.
$SnCl_2$	0.5 g.
$CuCl_2$	1.0 g.
Fe_2Cl_6	30 g.
HCl	50 cc.

Humfrey.—Emery paper finish may be used for specimen.

Copper ammonium chloride	120 g.
HCl (concentrated)	50 cc. (±)
H_2O	1000 cc.

The addition of HCl causes the copper deposit to adhere. Etching is therefore started with the neutral solution and continued until all traces of the scratches have disappeared. Then in successive applications the acidity of this solution is gradually increased up to the maximum. Alloy steels etch better with solutions of weaker acidity. After wiping away the deposited copper and drying, the surface is lightly rubbed with fine emery paper and the relief portions brought out in strong contrast. The section may be printed with ordinary printer's ink applied to the surface by means of a roller.

Dickenson.—First etch with 10-per-cent HNO_3. Then re-etch with:

Fe_2Cl_6	40 g.
$CuCl_2$	3 g.
HCl	40 cc.
H_2O	500 cc.

4. For etch tests to distinguish between wrought iron and steel, to develop the structure of welds, etc., the following rapidly-acting reagents are recommended, the percentages given being by volume:

(*a*)	Hydrochloric acid (sp. gr. 1.19)	10 per cent
	Sulfuric acid (sp. gr. 1.84)	30 "
	Water	60 "
(*b*)	Nitric acid (sp. gr. 1.42)	25 "
	Water	75 "

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METHODS FOR INDICATING DISTRIBUTION OF SULFUR.

The distribution of sulfur is usually shown by the sulfur print method. A solution of 2 to 3 cc. of concentrated H_2SO_4 in 100 cc. of water is used to moisten a sheet of matt-finish photographic paper. The specimen with its surface smoothed either with a fine file or grinding wheel is pressed firmly on the paper on which a brown mark indicates the sulfur-rich areas. About 60 seconds is usually sufficient to give a good print. The paper is then washed and fixed in hypo-sulfite solution.

With larger sections the paper is placed on their polished surface with care so that no air pockets occur. If a very dilute solution is used and a longer "etch" several prints can be obtained. Fresh solution can be added with absorbent cotton should the paper tend to become dry.

REFERENCES.

R. Baumann, *Metallurgie*, 1906, p. 416.
Stead, "Sulphur and Iron," Staffordshire Iron and Steel Institute, March, 1908.
Hatfield, "Cast Iron," p. 71, shows sulfur prints of pig iron.

METHODS USED FOR THE LOCATION OF MINUTE CRACKS BEFORE DEEP ETCHING.

Considerable differences of opinion have arisen as to the meaning of the results obtained by deep etching in transversely fissured rails, etc., because the presence of cracks in the material previous to etching

had not been demonstrated. The following method, however, can be used to locate them. The sample after careful polishing is magnetized and then immersed in kerosene or a similar liquid containing very fine iron dust in suspension. The particles of iron dust collect upon the face of the specimen and orient themselves to correspond to the shape of the cracks because of discontinuity in the metal which causes a change in the density of the magnetic flux. The samples are then washed in clean kerosene to remove as much as possible of the excess iron dust which clings to the surface.[1]

According to several authorities their existence has been proven by annealing the specimens prior to etching, because a pronounced decarburized area then occurs around these cracks.

METHOD OF PHOTOGRAPHING.

The camera should be arranged so that the specimen is illuminated by vertical light. After certain kinds of etching, *e. g.*, ammonium persulfate, the surface should be immersed in water, alcohol or light oil. For large specimens the surface may be covered with oil or glycerin.

PRINTING THE SURFACE.

The surface obtained by deep etching may be printed with printer's ink applied with a roller. The printing can be done on a glossy paper in a letter press. For small samples of wrought iron deeply etched a reproduction can be made using an ordinary ink pad and applying the specimen as in block printing.

MICROSCOPIC EXAMINATION.

LOCATION OF TEST PIECES.

The location of the test piece for microscopic examination is of prime importance. In the case of a casting of steel or cast iron, the section ought to be cut perpendicular to the surface so as to show the variation of structure from the outside to the interior. In the case of forged and rolled metal both cross and longitudinal sections should be examined, their location being determined by the nature of the forging, etc. For crankshafts definite locations are given with reference to the tension test specimens. For guns, tangential specimens are required and for microstructure these should be cut parallel to the axis, etc. No one specimen is of necessity representative. The usual method of taking a cross-section from rods and bars while showing segregation of the constituents fails to reveal the usual

[1] Rawdon and Epstein, *Technologic Paper No. 165*, Bureau of Standards (1920).

lamination in such material for which a longitudinal section is necessary. The location of test specimens may be determined by a preliminary macroscopic examination.

In defective material, the sample should be cut adjacent to the fracture or defect. When necessary the fracture can be protected during grinding and polishing by coating it with a heavy deposit of electrolytic copper, molten lead-tin solder or a mixture of litharge and glycerin. For hardened steel and other material liable to be tempered, fusible metals such as Rose's or Wood's alloys may be used.

METHOD OF POLISHING.

The method used for polishing specimens will depend primarily on the material to be examined and on the polishing equipment. In general, samples should not be over 1-in. square and their thickness should be less than the smallest dimension of the polished surface; otherwise there is a tendency to round off the edges during the process.

The softer material can be cut with a saw while harder metal may be cut with an emery disk or broken off with a hammer. A flat surface is at first obtained either by rubbing on a file held in a vise or by grinding on an emery wheel. In both cases it is necessary to avoid tearing the surface of the metal or causing it to flow. Perfectly smooth surfaces can be obtained by commercial surface-grinding machines.

Having obtained a flat surface in this way, the sample is next rubbed down on a series of emery papers, usually starting with No. 00 Commercial followed by Nos. 0 and 00 French Emery. These papers may conveniently be mounted on revolving disks. Rubbing on one paper is stopped as soon as the scratches from the last operation have been taken out. From the No. 00 French Emery the specimen may be taken to a revolving disk covered with broadcloth, preferably running in a horizontal position at such a speed that the polishing powders are not unnecessarily thrown off. For ordinary work, two such disks will be sufficient, the first armed with well-washed carborundum, 65 or a similar grade, while the second may be armed with well-washed alumina. This is preferable to rouge because it is much cleaner.

To obtain a fine polish it is a mistake to try to save time by hurrying through the papers because if this is done, when the specimen is etched, innumerable fine lines will be revealed in the ferrite. In some cases the appearance of the ferrite is actually blurred because the metal distorted in the grinding and by the coarse grades of emery has not been subsequently removed. Under no conditions should

buffing be tried, because this causes an actual flow of the metal and the structure is thereby obliterated.

No general rules can be laid down as to the method to be pursued, but common sense will tell what is right and what is wrong. For example, in grinding on the emery wheel a copious flow of water must be maintained, otherwise the surface of the sample will heat up and the structure of the metal will be modified thereby.

For material of small size, such as sheet and wire, numerous methods of mounting have been devised. For wire, various mounting media such as wax, a mixture of litharge and glycerin, fusible metals and the like can be used in a small brass container. For sheet metal, a pack can be built up of pieces of the sample with alternate layers of red fiber board, bakelite or other resistant material, the whole held together by two brass end pieces and two screws. The whole can then be polished down.

METHODS OF ETCHING.

The sample ought to be examined as polished in order to show up the non-metallic inclusions as well as cracks and other defects. In order to show up the structure of the metallic matrix various etching reagents have been used depending on the material being examined. The accompanying list gives the best of these reagents. For general work a 4-per-cent solution of picric acid in ethyl alcohol is recommended. This darkens the pearlite in steel and leaves the ferrite or cementite bright as the case may be. Long etching with picric acid in alcohol will develop the grain structure in very low carbon steel and in wrought iron. This may be done more rapidly with a 2 to 4-per-cent solution of nitric acid in ethyl alcohol (95-per-cent). For showing up pearlite alone, picric acid in absolute alcohol is best.

To distinguish between ferrite and cementite in high-carbon steels, the usual method is to boil in the sodium picrate solution, which darkens the cementite.

For hardened and tempered steel, picric acid may be used, but after etching, washing under the tap, and flooding with alcohol, the specimen should be dried by an air blast or if this is not available by shaking it in air. If the usual method of mopping on a soft towel be tried, the etching film will be spoiled.[1]

For the study of hardened and tempered steels under high magnifications other reagents have been devised such as those of Kourbatoff.

[1] To dry specimens without the use of alcohol:

After etching, wash in very hot water and dry in an air-blast. With this method the results obtained are as good as with the older method of using alcohol after washing in water. After etching with dilute nitric acid solutions, steels in the unhardened condition do not show the stains which generally appear after drying with alcohol.

For distinguishing between cementite and phosphide of iron in cast iron, either heat tinting or boiling with sodium picrate may be used, as recommended by Matweiff. This attacks the iron phosphide but leaves the cementite unattacked.

For revealing the segregation of the phosphorus in steel, various reagents have been used depending on the deposition of copper from a copper chloride solution, as given in the accompanying list of reagents.

Certain alloy steels, especially those high in the alloying elements, are very resistant to etching. For these special solutions have been devised such as ferric chloride for high-nickel material, caustic soda solution of hydrogen peroxide, etc., for high-speed steels.

In many cases after etching, the ferrite or cementite may be found to be more or less stained or colored. This can often be remedied by a light repolish on a chamois-skin pad. While this brightens up the ferrite or cementite, as the case may be, it markedly alters the appearance of the pearlite, giving it an abnormal structure, and therefore when this method is used, photographs should be so marked. The accompanying lists of reagents are commonly used.

REFERENCES.

Sauveur, "Metallurgy and Heat Treatment of Iron and Steel," 1920, pp. 42 and 62.

Tiemann, "Iron and Steel," 1919, p. 286.

Hoyt, *Metallography*, Vol. I, p. 63 (1920).

Wawrziniok, "Handbuch des Materialprüfungswesens," p. 497.

Czochralski, *Stahl und Eisen*, II, p. 1073, p. 1129 (1915). List of reagents, p. 1132.

Goerens, *Metallography*, p. 134.

Kerns, Foundry Data Sheets, June 1 and 15, 1920. Etching Solutions for Iron and Steel.

Kourbatoff, *Revue de Metallurgie*, 2, p. 169 (1905). Contribution a l'Etude Metallographique des Aciers Trempes.

Kourbatoff, *Revue de Metallurgie*, 3, p. 648 (1906).

Pamphlet No. 403, U. S. N. Bureau of Ordnance, October, 1916.

REAGENTS FOR ETCHING.

(*a*) SOLUTION FOR NORMAL IRON AND STEEL.

	(*a*)	(*b*)
Picric acid (*Igevsky*).—	4 g. picric acid.	5 g. picric acid.
	95 cc. ethyl alcohol, absolute.	100 cc. ethyl alcohol (95-per-cent).
Nitric acid.—	5 cc. HNO_3 (concentrated).	
	95 cc. ethyl alcohol (95-per-cent).	

Iodine.—1.25 g. I.
1.25 g. KI.
1.25 cc. H_2O.
to 100 cc. alcohol.

Hydrochloric acid (*Martens and Heyn, 1904*) (*hardened steel especially*).—
1 cc. HCl (sp. gr. 1.19).
100 cc. alcohol.
May dilute to 500 cc. water: 1 of HCl, using very weak current.

(*b*) SOLUTIONS FOR HARDENED STEEL.

Kourbatoff's Solutions.—

1. A. Solution.— 4 cc. HNO_3.
96 cc. amyl alcohol.
5 min., troosto sorbite brown, austenite yellow, martensite white.

2. C. Solution.—1 part amyl alcohol
1 " ethyl " } (1).
1 " methyl "
1 " of 4-per-cent HNO_3 in acetic anhydride (2).
Colors troostite and troosto-sorbite. Mix 1 and 2 just before using.

3. 2 parts methyl alcohol.
2 " ethyl "
2 " amyl "
1 " butyl "
3 " of 4 per cent HNO_3 in acetic anhydride.
For troostite.

4. 4-per-cent HNO_3 in methyl alcohol to which 1/10 its volume of 4-per-cent picric acid in ethyl alcohol is added.
Colors austenite, martensite and troosite differently.

5. D. Solution.—1 volume of 4-per-cent HNO_3 in ethyl alcohol.
3 volumes saturated solution of nitrophenol in ethyl alcohol.
10 min. colors troosto-sorbite and martensite needles.

6. B. Solution.—1 volume of saturated solution of ortho-nitrophenol in alcohol.
2 volumes of 20-per-cent HCl in amyl alcohol.
Differentiates the various constituents.

7. 1 volume of HNO_3 in alcohol
3 volumes of saturated solution of nitraniline.
Colors troostite, troosto-sorbite and martensite needles.

Benedicks.—5-per-cent meta-nitrobenzol sulfonic acid in alcohol 0.15″ darkens martensite more than austenite.

(*c*) SOLUTIONS FOR CARBIDES, ETC.

Kourbatoff.— 2 g. picric acid.
98 cc. of 25-per-cent NaOH in water.
Used boiling 5 to 10 min. Cementite colored. Also Fe_nW, Fe_2W_2C, etc., in tungsten steels while WC is unattacked. Ferrite unattacked.

Matweieff.—Neutral sodium picrate washed several times with distilled water.
Solution used boiling. 20 min. Iron phosphide attacked, cementite unattacked.

Yatsevitch.—10 cc. H_2O_2 (commercial).
20 cc. of 10-per-cent NaOH in water.
10–12 min. For high-speed steel. Use fresh. Tungsten carbide darkened.

Hilpert and Colver-Glauert.—3 to 4 per cent of a saturate solution (aqueous) of SO_2 in alcohol or water.
7 sec. to 1 min. For non-pearlitic steels and pig iron.

Murakami.—10 g. potassium ferricyanide.
10 g. potassium hydroxide.
100 cc. water.
Use hot. Distinguishes between carbide and tungstide in high-speed and in tungsten steels.

(*d*) SOLUTIONS FOR ALLOY STEELS.

Ferric chloride.—Fe_2Cl_6, 5 g.
HCl 50 cc.
Water 100 cc.
Used for austenitic nickel steels.

Electrolytic.—Aqueous solution of 0.5-per-cent NaOH with very weak current. On 110 volt circuit use two 4 c. p. lamps in series, connected with two wire terminal (platinum wire preferable). Flood specimen's surface with solution. Make contact with one wire at side and dip the other with the solution, moving it around to obtain uniform etch. Used for stellite, high chrome, etc.

METHODS FOR IDENTIFICATION OF NON-METALLIC INCLUSIONS.

Stead.—Dilute H_2SO_4 (1 : 3 H_2O). Bubbles from sulfides, none from silicates.

Law.—Uses an acid solution of lead or cadmium salt in gelatin. The sulfides form deep brown or yellow stain of cadmium or lead sulfide.
Electrical etching solution: Distilled water with 0.002-per-cent ammonium chloride or caustic potash solution used boiling. After a few minutes wash and dry with alcohol.
MnS unaltered.
Oxide completely removed.

Matweieff.—Action of hydrogen at high temperatures.
Oxides (MnO FeO)—reduced.
Silicates—unaffected.
Sulfides—unaffected.
Action of vapor of water at high temperatures.
Oxides—attacked.
Silicates—unattacked.
Sulfides—unattacked.
Action of organic acids.
Oxides—unattacked.
Silicates—unattacked.
Sulfides—attacked.

Matweieff.—Continued.

Distinction between FeO and MnO.
Reduction by hydrogen—repolished.
Dilute alcohol solution of $FeCl_3$.
If colored deep—MnO with some FeO.
MnO alone is not reduced.
If colored feebly—FeO.
Distinction between FeS and MnS.
FeS—colored by solution of tartaric acid.
MnS—very feebly colored.

Rohl.—Sulfides 1-per-cent acetic, citric, oxalic or picric acid in water.
FeS always more readily blackened in one minute. MnS blackened slightly after 45 seconds.
Picric acid gives most uniform results.
1-per-cent acetic or picric acid in ethyl alcohol can be used.
Etching by picric acid (4 g. acid+100 cc. amyl alcohol then by dilute HNO_3) (4 cc.+100 cc. amyl alcohol) then by concentrated hot NaOH solution. Dark brown color due to sulfides.
Sodium acetate 2 per cent aqueous—1 minute.
FeS—brownish tint.
MnS—very light.
Reduction Tests.
(1) $HgCl_2$ solution.
Sulfides covered with Hg especially FeS.
Repolishing (softly) FeS—corroded, MnS—not corroded.
(2) $AgNO_3$ solution. (3-per-cent solution boiling.)
FeS—uniform violet blue.
MnS—dove gray slightly darkened.
Repolishing:
FeS—reddish violet.
MnS—blue gray.
Rohl's Method of distinction:
(1) Organic acid 1 per cent in ethyl alcohol with 5 minutes etching.
FeS darkens more than MnS.
(2) A short preliminary etching. With 1 per cent picric acid in ethyl alcohol followed by tempering to dark yellow.
FeS—a beautiful dark blue to reddish violet.
MnS—dull gray to bright white.

SULFIDES.

McCance.—

Whiteley's Reagent { 5 g. gelatin + 20 cc. H_2O, soak for one hour and add 15 cc. glycerin. Heat till clear, add 0.05 g. tartar emetic in 1 cc. H_2O, filter and add 1 cc. dilute H_2SO_4. Apply warm.

Yellow ring forms around sulfides.

McCance's Reagent. Replace tartar emetic by 0.1 g. $AgNO_3$.
Black stain indicates sulfide.

FOR SILICATES AND OXIDES.

McCance.—

A. { HF..... 2 cc. absolute alcohol..98 cc. } For steels, about 3 sec. darkens sulfides, and silicates. Oxides unattacked.

B. { HF..... 8 cc. H_2O.....42 cc Alcohol.....50 cc. }

Comstock.—Uses boiling alkaline picrate of soda. MnS blackened and roughened. Silicates and oxides unaffected.

REFERENCES.

Stead, *Iron and Steel*, IX, p. 105.
Law, *Journal*, Iron and Steel Inst., II, 94 (1907).
Matweieff, *Revue de Metallurgie*, VII, p. 447.
Rohl, *Journal*, Iron and Steel Inst. Carnegie Memoir, IV, p. 28 (1912).
McCance, *Journal*, Iron and Steel Inst., 1–239 (1918).
Comstock, *Transactions*, A. I. M. E., LVI, 553 (1916).

BIBLIOGRAPHY OF ETCHING

Fry, "Etching to Develop Overstrain," *Stahl und Eisen*, Vol. 41, pp. 1093–1097 (1921); *Chemical and Metallurgical Engineering*, Vol. 27, p. 349 (1922). Method brings out markings in overstrained steel. After polishing, the specimens are heated to 200° C. for one-half hour.

Etching Solution:

Hydrochloric Acid (concentrated)	40 cc.
Water	30 cc.
Ethyl Alcohol	25 cc.
Cupric Chloride Crystals	5 g.

After immersion, the specimen is rubbed with finely powdered cupric chloride on a rag moistened with the etching solution until desired contrast is obtained, dried without rinsing, washed with alcohol and again dried. The dark portions are due to the presence of iron hydride and indicate the amount of plastic deformation the metal has received.

Gill and Bowman, "Metallography of High-Speed Steel," *Transactions*, Am. Soc. Steel Treating, Vol. II, pp. 184 to 205. Picric acid used for annealed samples, 6 to 8 per cent HNO_3 in alcohol best for hardened specimens. A solution of NaOH and H_2O_2 and a solution of $K_3Fe(CN)_6$ used for tungstides.

Krivobok and Sauveur, "Use of Sodium Picrate in Revealing Dendritic Segregation in Iron Alloys," Am. Inst. Mining and Metallurgical Engrs., February, 1924.

Loskicwiz, "Time of Attack of Micrographic Reagent on Iron-Carbon Alloys," *Revue de Metallurgie Memoires*, Vol. XIX, pp. 681 to 687 (1922). Gives time of etching with picric and nitric acid solutions in alcohol at three temperatures (16, 24 and 35° C.) for plain carbon steels. Gives also curves showing time of attack for pearlite, sorbite, troostite and martensite in a 0.9-per-cent carbon steel, and a table of basis reagents used to color cementite.

Pilling, "Micrographic Detection of Carbides in Ferrous Alloys," Am. Inst. Mining and Metallurgical Engrs., February, 1924.

Silicon steels up to 6 per cent are attacked by water during polishing. It is necessary to use alcohol as polishing lubricant in the last stages of preparation and to avoid all etching reagents having an aqueous base. Boiling alkaline sodium picrate solution attacks the silico-ferrite.

A new reagent consists of a dilute solution of nitric acid and methyl alcohol in nitro-benzol. Make an anhydrous stock solution of 20 per cent nitric acid in methyl alcohol. The etching reagent consists of 40 drops of this solution in 50 cc. of nitro-benzol. Etch by immersion for 20 seconds. Store in dark-colored bottles.

Strauss, B., and Fry, A., "Formation of Cracks in Boiler Plates," *Stahlund Eisen*, Vol. 41, p. 1133. Metallographic illustrations obtained by same reagents as given under Fry, above.

MEANS FOR THE IDENTIFICATION OF NON-METALLIC INCLUSIONS.

As Polished

FeS.	Brownish yellow.
MnS.	Slate blue, smooth.
FeS_xMnS_y.	Slate blue to brown, may show duplex structure.
FeO.	Slate blue, rough, a little darker than MnS.
MnO.	Similar.
Mn—Silicate.	Greenish tinge, smooth and greasy.
Fe—Silicate.	Black and greasy.
Al_2O_3.	Tiny hard rounded grains, never elongated by rolling, etc.
Sand Grains.	Angular form, convex side, greasy appearance standing in high relief.

Titanium nitride or cyanonitride. Pink or yellow cubic crystals.

	Sulfides.	Oxides.	Silicates.
H_2SO_4 (1 : 3 H_2O)	Gas bubbles.	No action.	No action.
Pb or Cd. salt in gelatin.	Brown or yellow stain.	" "	" "
McCance's Reagent, $AgNO_3$ in gelatin.	Black stain.	" "	" "
Acetic, citric, oxalic, etc.	Attacked.	" "	" "
Boiling sodium picrate.	Black and rough.	" "	" "
H or H_2O at 600° C.	No change.	Reduced or attacked.	" "
2 cc. HF in alcohol, 3 sec. etch.	Darkened.	No action.	Darkened.
Electrolysis (0.002-per-cent NaOH).	No change.	Removed.	No change.

	FeS	MnS
As polished	Brown-yellow.	Slate blue—smooth.
Tartaric acid	Colored.	Colored, less.
1-per-cent picric alcohol. 5 min	Blackened.	Less so.
Ditto. Heat tint to dark yellow	Blue-violet.	Dull gray white.

	FeO	FeO_xMnO_y	MnO
H at 600°	Reduced.	Reduced.	Unreduced.
Electrolysis (0.002-per-cent NaOH)	"	"	"
Alcohol Fe_2Cl_6 solution after electrolysing and repolishing	Feeble color.	Deep color.	Not reduced.

STANDARD METHODS
OF
METALLOGRAPHIC TESTING OF NON-FERROUS METALS AND ALLOYS[1]

Serial Designation: E 5 – 27

These methods are issued under the fixed designation E 5; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1923; ADOPTED IN AMENDED FORM, 1924; REVISED, 1927.

MACROSCOPIC EXAMINATION

In order to show up both chemical and crystallin heterogeneity, sections of metals and alloys should be more deeply etched than for microscopic examination. The dendritic structure in castings, dendritic shrinkage cavities, blowholes and other porosity, the flow of metal due to cold working, etc., are brought out.

After cutting the section, it is filed or ground smooth and flat, then rubbed on various grades of emery paper down to No. 00 French, so that all effects of surface cold working due to cutting are eliminated. After cleaning the surface of all grease it is ready for etching.

ETCHING SOLUTIONS

For macroscopic etching, most of the reagents used for microscopic examination may be used, but the time of etching is usually much longer. Those solutions which give maximum grain contrast are usually to be preferred.

For copper and its alloys, a 50-per-cent aqueous solution of nitric acid is recommended. Also an ammoniacal solution of copper ammonium chloride is very satisfactory.

The specimen is either immersed in the solution or flooded with it until the structure shows up strongly. It is then well washed with running water, flooded with alcohol and dried. If the structure is to be recorded, it should be photographed immediately. The surface

[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee E-4 on Metallography.

may be preserved for reference by covering with a thin coat of brass lacquer (a solution of gun cotton in Amyl Acetate) or similar preparation.

For aluminum and its alloys, a solution of HF-HCl (Solution No. 2) is recommended. A 10 per-cent aqueous solution of NaOH and a 10-per-cent HF also give good results. In copper-bearing alloys the latter solution should be followed by a cleaning in cold concentrated HNO_3.

For lead and its alloys, 10 per cent of nitric acid in water is recommended. For lead ingots, acetic acid gives excellent results.

MICROSCOPIC EXAMINATION

LOCATION OF TEST PIECES

In the case of castings, the sections ought to be cut perpendicular to the surface and show the variation of structure from outside to center. For rods, sheet, etc., transverse, longitudinal and frequently oblique sections should be examined. For large forgings, the threaded ends of the tension test pieces can usually be used by cutting a longitudinal section about one inch in length. No one specimen is of necessity representative. As in iron and steel, the usual method of taking a cross-section from rods and bars while showing segregation, fails to reveal lamination. Surface sections of sheet metal are usually taken, but for cold-worked metal, transverse, longitudinal and frequently oblique sections are also necessary.

For material of small size, the methods of mounting recommended for iron and steel can be used as described in the Standard Methods of Metallographic Testing of Iron and Steel (Serial Designation: E 3) of the American Society for Testing Materials.[1]

METHOD OF POLISHING

The methods recommended for iron and steel as described in the Standard Methods of Metallographic Testing of Iron and Steel (Serial Designation: E 3) of the American Society for Testing Materials[1] are applicable for the harder alloys. For soft metals and alloys, emery wheels cannot be used. The sample is rubbed on a file held in a vise, care being taken that the surface is cut and not torn. The file must be kept free from embedded particles of metals or the surface is bound to be torn.

In using the emery papers, only very little pressure may be used

[1] See p. 756.

or the surface is apt to flow. For soft metals, rubbing by hand is recommended. If revolving disks are used, low speed must be maintained to prevent spoiling the surface. From the No. 00 French paper the specimen may be taken to a revolving disk covered with broadcloth and armed with well-washed alumina. Again, for soft metals, if the pressure is too great the surface is apt to be spoiled. Buffing cannot be used. For very soft metals, such as lead and some of its alloys, even the most careful polishing leaves a film of "flowed" metal. Such samples can be etched fairly deeply with 10 per cent of nitric acid in water and then given a very light repolish with alumina, the surface of the disk being kept very moist. It is then washed free from polishing powder and dried with alcohol.

In the preparation of specimens of aluminum and its alloys, the same precautions must be followed which are recommended for other soft metals. It is further recommended that following the cut on the file, two coarse emery papers, No. 2 and No. 1, be used, preceding the use of the finer metallographic polishing papers. The papers should be prepared by applying a solution of paraffin in kerosine and working well into the surface. The polishing must be done by hand. The papers may be used either as so prepared or moistened with additional solution. It is not always necessary to use this solution on the coarse papers, No. 2 and No. 1. The hand polishing may be stopped at either No. 000 or No. 0000 paper and the polishing continued on a wheel revolving at approximately 200 r.p.m. For the first cut on the wheel, a coarse grade of broadcloth is used with a grade of abrasive similar to 65-*F* alundum. The next cut is made using a softer broadcloth and "heavy magnesium oxide," applied as follows: The pad is moistened with distilled water and approximately one teaspoonful of powder applied evenly to the surface and thoroughly rubbed in, all hard and coarse particles being brushed off with the hand. After the scratches left by the 65-*F* material have been removed the pad is washed clean and a smaller quantity of powder worked in as before. This time the cut is made at right angles to the first treatment. This procedure may be repeated several times until the specimen shows a brilliant, reflecting surface, and under the microscope the aluminum solid solution matrix appears clear white and the constituents stand out in even colors, free from tarnish. Only distilled water should be used during the polishing with the magnesia powder, otherwise there is danger of forming particles of carbonate, which are harsh and scratch the specimen. It is good practice frequently to raise the specimen from the pad and revolve it 180 deg. before replacing. The pressure and quantity of water to

be used can only be determined after considerable practice and varies with the nature of the alloy.

METHODS OF ETCHING

The sample is first examined for non-metallic inclusions, cavities and the like. The structure is then developed by etching with a suitable reagent, a list of which is given below. No one reagent can be said to be the best for any alloy or group of alloys. Cast metal behaves quite differently from both hot and cold-worked or annealed material.

For copper and its alloys a 50-per-cent aqueous nitric acid solution is recommended. The sample is immersed until the structure shows up, then washed with water and dried with alcohol.[1] This reagent, however, is liable to cause pitting.

For wrought brass, bronze, German silver, etc., the best reagent is ammonia and hydrogen peroxide. About 10 cc. of strong ammonia are placed in a watch glass, 1 or 2 cc. of peroxide (3.6-per-cent) added and applied to the surface of the specimen with a small wad of cotton, rubbing gently till the grain structure appears.

For cast gun metal, this method shows up the coring of the dendrites but the eutectoid has little contrast with the saturated parts of the alpha. If the sample is then flooded with Grard's Solution No. 1 until the alpha darkens slightly, the eutectoid still remains bright blue-white and shows up in marked contrast.

Nickel and its alloys frequently show a peculiar pitting. If a 50-per-cent aqueous nitric acid solution be used, small pits appear with colored rings or halos. Merica's nitric-acetic acid gives much better results.

For wrought nickel alloys, concentrated hydrochloric acid is recommended. The action is very slow but the contrast is excellent.

The etching characteristics of copper and of nickel alloys are thoroughly dealt with by Rawdon and Lorentz.

For aluminum and its alloys sodium hydroxide shows up the grain structure but is liable to cause roughening. The weaker solution is recommended for details of structure and may be further diluted.

Etching reagents for the identification of constituents in aluminum and its alloys are generally unsatisfactory. Reagents intended to differentially color specific constituents are uncertain and their

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[1] To dry specimens without the use of alcohol:

After etching, wash in very hot water and dry in an air-blast. With this method the results obtained are as good as with the older method of using alcohol after washing in water. After etching with dilute nitric acid solutions, steels in the unhardened condition do not show the stains which generally appear after drying with alcohol.

action varies in different alloys and especially under different conditions of polishing. For this reason it is recommended that the specimens be carefully polished and examined in the unetched condition. If a light filter is used to give a source of light approximating daylight, the constituents will appear as described below:

UNETCHED CHARACTERISTICS

Constituent	Color	Usual Shapes	Characteristics
Si	Slate.	Irregular plates.	Easily recognized.
$FeAl_3$	Purplish gray.	Needles.	Tendency to purple tinge with relief polishing.
Other iron constituents	Purplish gray.	"Chinese script" and needles.	Less tendency to purplish tinge. Occurrence due to other elements, notably Si. Composition uncertain.
$CuAl_2$	Clear with pink tinge.	Gobs, stringers.	Tendency to polish in relief and tarnish. Appears bright on passing out of focus.
$MnAl_3$	Flat gray to watery.	Angular plates, often hollow. Arrowheads.	Does not polish in relief, but prolonged polishing gives watery appearance. In high-manganese alloys shapes are very characteristic.
Mg_2Al_3	Very faint watery.	Gobs, stringers.	Same form as $CuAl_2$ but much softer. Sometimes difficult to distinguish from aluminum matrix.
$NiAl_3$	Light gray.	Needles.	Difficult to distinguish from $FeAl_3$.
Mg_2Si	Slate gray to iridescent blue.	Skeletons and rounded particles. Angular primary particles.	Very careful polish gives even slate-gray particles which are easily tarnished and are turned black or eaten out by too much water in polishing.

With a little experience in the examination of specially prepared known standards, the identification of these constituents when they occur in sufficiently large particles is relatively simple and etching reagents for distinguishing them are generally unnecessary. When the particles are smaller, the identification becomes extremely difficult, but etching reagents which satisfactorily color large particles fail to identify the smaller particles.

In studying a specimen containing very small particles such as finely precipitated $CuAl_2$, there may be sufficient surface flow to completely obscure the particles. To guard against this condition and to reveal grain boundaries and other structural features, it is desirable to swab the specimen lightly with a soft cotton swab saturated with a dilute solution of HF (0.5 to 1-per-cent preferred).

The harder constituents usually show up as polished, *e. g.*, Si, $FeAl_3$, $CuAl_2$, $NiAl_3$, and Mg_2Si. To differentiate between them, the last three solutions can be used.

The white metals are usually easy to etch if properly polished. For the lead-tin alloys, however, the usual methods do not work so well. It is better to etch rather deeply with nitric acid and then very lightly repolish on a chamois skin pad until the structure shows up in marked contrast.

REAGENTS FOR ETCHING

(*a*) SOLUTIONS FOR COPPER AND COPPER ALLOYS

Nitric Acid.—50 cc. nitric acid (concentrated)
50 cc. water

Ammonia.—10 cc. ammonia (concentrated)
1 cc. hydrogen peroxide (Marchand)

Grard No. 1.—5 g. ferric chloride
50 cc. hydrochloric acid
100 cc. water

Grard No. 2.—19 g. ferric chloride
6 cc. hydrochloric acid
100 cc. water

Ammonium Persulfate.—10-per-cent aqueous solution made just before use. This solution is improved materially by the addition of a few drops of ammonia just before using.

Heyn's Solution.—5 g. copper-ammonium chloride
120 cc. water
Add ammonia until precipitate which forms redissolves

(*b*) SOLUTIONS FOR NICKEL, MONEL METAL, CUPRO-NICKEL

Merica's Solution.—50 cc. of 70-per-cent nitric acid
50 cc. of 50-per-cent acetic acid

International Nickel Co.—20–40 cc. nitric acid
40–30 cc. 75-per-cent acetic acid
40–30 cc. acetone

Hydrochloric Acid.—(Concentrated)

(*c*) SOLUTIONS FOR ALUMINUM AND ALUMINUM ALLOYS

Solution	Reagent	Concentration	Specific Use	Authority	Reference Number[1]
No. 1	HF and HCl[a]	10 to 20-per-cent alcoholic HF and concentrated HCl	Macroscopic	Czochralski	(5)
No. 2	HF and HCl[a]	10 parts HF, 15 parts HCl, 90 parts H_2O	Macroscopic	Flick	(18)
No. 3	HF	0.1 to 10-per-cent	General	Various	(7, 8, 9, 10, 11, 12, 16, 17, 19, 20, 21)
No. 4	NaOH	0.1 to 10-per-cent	General	Various	(7, 8, 9, 10, 11, 12, 16, 17, 19, 21)
No. 5	NaOH	0.1 per cent in 10 to 50 per cent of alcohol	General	Merica	(11, 12)
No. 6	HNO_3	1 per cent in alcohol	Mg_2Al_3	Hanson	(10)
No. 7	HNO_3	10 per cent in alcohol	Mg_2Al_3	Hanson	(10)
No. 8	HNO_3[b]	20-per-cent quench	$CuAl_2$	Hanson	(10)
No. 9	HNO_3[b]	25-per-cent quench	"X" Const. from $FeAl_3$	Dix	(14)
No. 10	Ferric sulfate	10-per-cent	$CuAl_2$ from $FeAl_3$	R. J. Anderson	(17)
No. 11	Picric acid	4 per cent in alcohol	$CuAl_2$	A. Meyer	(15)
No. 12	H_2SO_4[b]	10-per-cent at 60 to 70° C.	$FeAl_3$	A. Meyer	(15)

[a] Czochralski originally etched for grain by using from 10 to 20 per cent of concentrated HF in 100 cc. absolute alcohol, followed by dipping in concentrated HCl solution. Flick has very satisfactorily modified this etch by using a single solution prepared as follows: 10 cc. of commercial HF and 90 cc. of distilled water and 15 cc. of concentrated HCl.

[b] By the 20 and 25-per-cent nitric acid quench is meant the procedure of heating the solution to exactly 70° C. and immersing the specimen for a period of from 2 or 3 seconds to 30 seconds and then immediately quenching the specimen in cold water. This same procedure may be used with the sulfuric acid etch, although the quench is not essential

[1] For list of references, see p. 776.

(*d*) SOLUTIONS FOR WHITE METALS (LEAD, TIN OR ZINC BASE)

Nitric Acid.—2-per-cent alcoholic solution. For tin-rich alloys
Nitric Acid.—5-per-cent aqueous solution. For lead-rich alloys
Hydrochloric Acid.—5-per-cent aqueous solution. For zinc-rich alloys

The above list gives the principal reagent used for etching the chief commercial alloys. Numerous other methods have appeared in the literature, each worker apparently preferring to develop his own method. The papers by Hudson, Czochralski and Guertler covering etching reagents enumerate most of the ones which have had any vogue. Amongst these less used reagents the following may be mentioned:

Gold, Platinum, etc.—Aqua regia
Zinc (Timofeeff).—94-per-cent nitric acid } A few drops added to 100 cc. of water
6-per-cent chromic acid } before use
Tin.—5-per-cent alcoholic solution of hydrochloric acid
Magnesium and its Alloys.—2-per-cent nitric acid in water, 10 sec.
Tungsten.—(1) Boil in ammonia and hydrogen peroxide, or hydrogen peroxide alone.
(2) Electrolytic etch. 15-per-cent NaOH. 20 milliamperes per square centimeter. About 5 minutes.
(3) 2.5-per-cent water solution of potassium ferrocyanide to which a few drops of ammonia are added just before use. Broadcloth or rubber is moistened with the solution and the specimen gently polished on the surface so prepared.

ELECTROLYTIC ETCHING

Electrolytic etching has been advocated by many workers, notably Le Chatelier, for brass and other alloys. The newer methods. as, for example, ammonia with hydrogen peroxide give better results, For certain materials however, electrolytic etching gives excellent results, especially where the samples are very resistant to ordinary etching reagents: for example, tungsten, certain of the nickel chromium alloys, white gold, etc. A simple method is to connect two short platinum wires to the electric light circuit of 110 volt (direct current) through a four-candle-power lamp. Place the specimen on the anode wire so that its upper surface is perfectly level. Drop on enough dilute sodium hydroxide to cover the whole surface and then dip the cathode wire into the electrolyte. In order to get a uniform etch, the end of the wire should be bent at right angles and moved back and forth above the surface of the specimen to be etched. As soon as the structure is visible to the eye, the sample may be washed and dried in alcohol in the usual way. This gives a quick although somewhat rough and ready method but one which usually works very well.

The specimen is held face downwards by a flexible clip attached to the positive connection. The electrolyte is placed in a suitable dish in which the negative pole is immersed. The electrolyte surface is raised until it wets the surface of the specimen and then lowered slightly so as to produce a surface tension contact between the specimen and the solution. The results are very much superior to the old method of complete immersion of the specimen.

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General

(1) Rawdon and Lorentz, "Metallographic Etching Reagents I. For Copper," U. S. Bureau of Standards *Scientific Paper No. 399*.

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(4) Hudson, "Etching Reagents and Their Applications," *Journal*, Inst. of Metals, Vol. XIII, p. 193.

(5) Czochralski, "Etching Phenomena and Reagents," *Stahl und Eisen*, 35 (2), pp. 1073 and 1129 (1915).

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(7) Anderson, R. J., "Metallography of Aluminum," *Chemical and Metallurgical Engineering*, XVII, pp. 64, 172 (1918).

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(16) Daniels, S. D., "Cast Alloys of Aluminum Containing Small Amount of Magnesium," *Industrial and Engineering Chemistry*, 16, p. 1243 (December, 1924).

(17) Anderson, R. J., "Metallurgy of Aluminum and Aluminum Alloys," Baird and Co. (1925).

(18) Flick, F. B., "Etching Aluminum and Its Alloys for Macroscopic and Microscopic Examination," *Transactions*, Am. Inst. Mining and Metallurgical Engrs. (February, 1925).

(19) Dix, E. H., Jr., "A Note on the Microstructure of Aluminum-Iron Alloys of High Purity," *Proceedings*, Am. Soc. Testing Mats., Vol. 25, Part II, p. 120 (1925).

(20) Daniels, S. D., "Sand-Cast Aluminum-Manganese Alloys," *Industrial and Engineering Chemistry*, 18, p. 2 (February, 1926).

(21) Dix, E. H., Jr., and Richardson, H. H., "Equilibrium Relations in Aluminum-Copper Alloys of High Purity," Am. Inst. Mining and Metallurgical Engrs. (February, 1926).

(22) Vilella, J. R., "Delving into Metal Structures, Part III," *Iron Age*, Vol. 117, pp. 903–907, 1926.

This is the third of a series of articles presenting new etching reagents. J. R. Vilella has modified an HF-HNO_3 reagent by using glycerin as a solvent. The development of the microstructure of aluminum alloys by this etch is discussed. The author states that different constituents are readily identified and has presented several micrographs to illustrate the etching effects. A general discussion of etching is also included.

(Abstractor's Note: The etching information presented is of value but the etching reagent has limitations and is not to be relied upon unless all other conditions are standardized.)

BIBLIOGRAPHY OF ETCHING

Chemical and Metallurgical Engineering, Vol. 24, p. 207 (1921). Gives list of the common reagents used by the Bureau of Standards, with notes on suitability. (See Bureau of Standards *Circular No. 113* (1921.)

Adcock, "Internal Mechanism of Cold-Work and Recrystallization in Cupro-Nickel," *Journal*, Inst. of Metals, Vol. XXVII, p. 74 (1922)—No. 1. Gives method of electrolytic etching in a solution of 100 g. citric acid per liter of water. Add 1 drop concentrated HNO_3 per 20 cc. of solution. For ordinary microsections 0.1 ampere is sufficient. (A tungsten lamp in series on a 110-volt circuit).

Rutherford, "Etching Lead and Lead Alloys," Private communication to Committee E-4, Rutherford, Western Electric Co. Samples flattened on coarse file, smoothed on fine file, polished on broadcloth wheel with magnesia.

Etch with:

Glacial Acetic Acid	3 parts
9-per-cent H_2O_2	1 part

for 10 to 30 minutes. Dry with alcohol and clean in concentrated nitric acid. The nitric acid is removed by sudden immersion in a larg e volume of water For pure lead and lead-tin alloys, the nitric acid cleaning may be omitted.

Strauss, "Etching Aluminum Bronze," *Chemical and Metallurgical Engineering*, Vol. 28, p. 852 (1923).

STANDARD RULES GOVERNING THE PREPARATION OF MICROGRAPHS OF METALS AND ALLOYS[1]

INCLUDING RECOMMENDED PRACTICE FOR PHOTOGRAPHY AS APPLIED TO METALLOGRAPHY

Serial Designation: E 2 - 27

These rules are issued under the fixed designation E 2; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1917; ADOPTED IN AMENDED FORM, 1920; REVISED, 1924, 1927.

STANDARD MAGNIFICATIONS

General Use.

1. The standard magnifications for general use in making micrographs, expressed in diameters, shall be as follows:

10, 25, 50, 75, 100, 200, 500, 1000.

2. For general use in Society reports, and for showing grain size, the following magnifications are recommended:

MATERIAL.	CAST.	WROUGHT.
Steel and Ferrous Materials	100	100
Copper	50 and 100	75
Copper-Zinc Alloys	50 " 100	75
Copper-Nickel Alloys	50 " 100	200
Copper-Nickel-Zinc Alloys	50 " 100	200
Lead-Tin-Antimony Alloys[2]	50 " 200	...

Reproduction of Micrographs.

3. (*a*) Reproductions of micrographs in publications shall be made of exact standard magnifications except in those special cases where the details of structure are to be illustrated.

(*b*) If micrographs submitted for publication are not of standard magnification, they shall be enlarged or reduced to the nearest standard size. The actual magnification appearing in print shall be stated under the micrograph. See Paragraph (*d*).

(*c*) To facilitate the reproduction, authors should be advised that their micrographs should be of proper size to fit the printed page, and in order to conserve space that micrographs be printed in the form of squares.

[1] Under the standardization procedure of the Society, these rules and recommended practice are under the jurisdiction of the A.S.T.M. Committee E-4 on Metallography.

[2] Including those containing small percentages of copper.

(*d*) With each micrograph shall be printed an explanatory title, together with actual magnification, etching medium, treatment, etc., indicating what the author intends to show, so that it will not be necessary to search the text for general information. With micrographs at magnifications of approximately 500 diameters and above, the numerical aperture of the objective and the type of illuminator shall be given.

(*e*) Photographs in which the magnification is less than 10 diameters are usually made with photographic lenses or single magnifiers. These will be considered as "macrographs."

With each macrograph should be printed an explanatory title, together with the actual magnifications, method of illumination, and general treatment indicating what the author desires to illustrate, so that it will not be necessary to refer to the text for general information.

LENSES

Lenses.

4. For obtaining the magnifications recommended, the following types of lenses are suggested as suitable for general commercial work:

(*a*) For magnifications from 20 to 30: A photographic lense of approximately 35-mm. focal length, to be used without ocular.

(*b*) For magnifications from 30 to 75: A 32-mm. objective with Huyghens ocular (approximately ×5).

(*c*) For magnifications from 75 to 150: A 16-mm. objective with Huyghens ocular (approximately ×5).

(*d*) For magnifications from 250 to 500: A 4-mm. objective (preferably apochromatic) with projection ocular.

Directions.

5. (*a*) All objectives should be corrected for use without cover glasses.

(*b*) In using one of the lens combinations given above, the length of the camera bellows may be adjusted to give the exact magnification desired.

It should be borne in mind, however, that increasing the magnification by increasing the length of the camera bellows adds nothing to the detail of the micrograph. This depends mainly upon the resolving power of the objective used.

(*c*) The magnification shall be determined by accurately measuring the image of a stage micrometer scale, and not by estimation from lens combinations, or microscope or camera adjustments.

GRAIN SIZE

Definition of Grain.

6. (*a*) *Alloys Consisting of but One Type of Crystals* (*e. g.*, copper, alpha brass, etc.): In counting individual grains the original crystal, including the twinned layers, shall be called one grain.

(*b*) *Alloys Consisting of Two Metallographic Components* (*e. g.*, steels, Muntz metal, etc.): The original grain which has given rise to the aggregation of the two components shall be taken as the unit when determinable and the individual component in other cases.[1] When grain size is included in actual specifications, the term should always be defined in such specifications.

Method of Measurement of Grain Size.

7. For measuring grain size, two methods are recommended depending upon the condition of the material:

(*a*) *For Material in which the Grains are Equi-axed* (*e. g.*, most metals in the cast and in the annealed state): The planimetric method as modified by Jeffries (See Note below) is recommended for use as being very accurate and rapid. It is recommended that the circular area used should always include at least 50 grains.

(*b*) *When the Grains are not Equi-axed* (*e. g.*, in strained materials): Heyn's intercept method should be used, the average grain size being determined by counting the number of grains at a given magnification along a line of known length on two axes at right angles to each other, one axis being parallel to the direction of rolling. In some cases a third count along a line perpendicular to the other two may be desirable. This will necessitate the preparation of another polished surface.

Numerical Expression of Grain Size.

8. The grain size as determined by the planimetric method, Section 7 (*a*), should be expressed as the number of grains per unit area (square inch or square centimeter). This may also, but less preferably so, be expressed as the average grain area; or the average linear dimension of the grain may be given. The grain size as determined by the intercept method, Section 7 (*b*), should be expressed by giving the average number of grains per linear unit in the two directions; or the average number per unit area together with the ratio of length to breadth of grain (L/B) may be given.

Use of Grain Size in Specifications.

9. If grain size is to be included in specifications, it should be expressed as the maximum or minimum allowable as determined above. It is recommended that only in extreme cases should grain size be made the sole basis of rejection of material.

NOTE

JEFFRIES' METHOD FOR GRAIN-SIZE MEASUREMENTS.[2]

A circle 79.8 mm. in diameter is drawn on the rough side of a ground-glass screen, the center of the circle being near the center of the rectangular section of the screen. This ground glass is mounted in a frame which fits a metallographic camera, the smooth side of the glass being on the outside. When the image of the

[1] See U. S. Navy Specifications, 49-S-2-c. p. 7.

[2] This method has been condensed from the paper by Zay Jeffries appearing in *Chemical and Metallurgical Engineering*, Vol. XVIII, p. 185 (1918).

specimen for grain-size determination is focused on the screen, the circle will be plainly visible and its circumference should be well within the image.

When the image is properly focused the grains intersected by the circumference of the circle are checked and counted. Since the check marks must be made on the smooth side of the glass, a soft red pencil, such as is used in laboratories for marking beakers and flasks, will be found satisfactory. The marks used to indicate the boundary grains are usually short, straight lines intersecting the circumference of the circle and perpendicular to it. The completely included grains are next checked and counted, after which the red marks are erased from the glass with a dry cloth. The specimen can then be moved and other measurements made as desired.

One-half the number of grains intersected by the circumference of the circle, added to the number of completely included grains, gives the number of equivalent whole grains within the circle. If the equivalent number of whole grains within the circle measured at a certain magnification be multiplied by the number in the third column of Table I opposite the magnification used, the product will be the number of grains per square millimeter.

TABLE I.

Magnification Used (=m).	Diameter of Circle, mm.	Multiplier to Obtain Grains per Square Millimeter (=f).
Full size	79.8	0.0002
10	"	0.02
25	"	0.125
50	"	0.5
75[a]	"	1.125
100	"	2.0
150	"	4.5
200	"	8.0
250	"	12.5
300	"	18.0
500	"	50.0
750	"	112.5
1000	"	200.0
1500	"	450.0
2000	"	800.0

[a] At 75 diameters, if a circle 84.5 mm. in diameter, or a rectangle having an area of 5625 sq. mm. is used, the factor f becomes unity.

A circle 79.8 mm. diameter has an area of 5000 sq. mm. If it is desired to use a rectangle of the same area in place of a circle for the determination, convenient sizes are given as follows:

70.7 by 70.7 mm.
65 " 77 "
60 " 83.3 "
55 " 91 "
50 " 100 "

Since each of these rectangles has an area of about 5000 sq. mm., the multipliers given in Table I can be used for any one of them, or any other rectangle having an area of 5000 sq. mm. To make a grain-size determination with a rectangular in place of a circular area, the grains intersected by the periphery of the rectangle should be counted, one-half the number added to the completely included grains and the result will be the number of equivalent whole grains within the rectangle. If the determination is made at one of the magnifications given in Table I, the number of grains per square millimeter can be obtained by multiplying the equivalent number

of whole grains within the area by the multiplier (f) opposite the magnification used. The rectangle could be used on a ground glass as described above for the circle, or it could be used on a micrograph.

Some metallographists prefer to refer to the grain size in terms of the diameter of the average grain in millimeters, or the area of the average grain in μ^2. The following simple formulas will be found helpful in these cases:

$$x = \tfrac{1}{2} w + z$$

$$f = \frac{m^2}{5000}$$

$$n = fx$$

$$d = \frac{1}{\sqrt{n}}$$

$$a = \frac{1{,}000{,}000}{n}$$

where w = number of boundary grains;
z = number of completely included grains;
x = equivalent number of whole grains in 5000 sq. mm. (circle 79.8 mm. in diameter or rectangle having area of 5000 sq. mm.);
m = magnification used;
f = multiplier to obtain number of grains per square millimeter;
n = number of grains per square millimeter;
d = diameter of average grain in millimeters;
a = area of average grain in μ^2.

After considering various criticisms, owing to the fact that 75 diameters has become an established practice for use in illustrating the structure and grain size of wrought copper and the copper-zinc alloys, and that a large volume of work has been done using this magnification, it seems advisable to retain a magnification of 75 diameters for this class of material.

RECOMMENDED PRACTICE
FOR
PHOTOGRAPHY AS APPLIED TO METALLOGRAPHY

10. The subject of photography as applied in metallography can be conveniently divided into the following sections:

I. Magnifications;
II. Lenses;
III. Illumination of Specimens;
IV. Photographic Materials.

I. MAGNIFICATIONS

11. In addition to the magnifications specified in Section 1, a magnification of 5 for use in the preparation of macrographs is recommended.

II. LENSES

12. In Table II have been grouped the various lenses and combination of lenses, which will be found convenient for obtaining different magnifications.

III. ILLUMINATION OF SPECIMENS

13. For use with objectives of 32-mm. focal length or less, all of which are used in combination with oculars, vertical illumination (*i. e.*, normal to the surface under observation) is usually necessary. Either the plane-glass or mirror type of illuminator (the latter including the totally reflecting prism) in which the reflector is placed behind the objective may be used. For best results, the condition of "critical illumination," that is the optical distance from the source of light

TABLE II.—LENSES FOR VARIOUS MAGNIFICATIONS.

Linear Magnification	Objective		Ocular	
	Type	Focal length (approximate), mm.	Type[1]	Remarks
10 or below..	Photographic.....	72	none	
10 to 20.....	Photographic.....	48	none	
20 to 30.....	Photographic.....	35	none	
30 to 75.....	Achromatic.....	32	Huyghens or similar	
75 to 150....	Achromatic.....	16	Huyghens or similar	
200.....	Achromatic or apochromatic	8	.....	Compensated and "Projection" for apochromatic objectives.
200 to 500...	Apochromatic preferred...	8	.....	Compensated for large fields.
		4	.....	Compensated for maximum resolution of fine structure.
1000.....	Apochromatic.....	4	.....	Compensated for large fields.
		2	.....	Compensated for maximum resolution of fine structures.

[1] The magnifying power of the ocular should be such that the desired size of projected image can be obtained with a moderate length of bellows.

(real or apparent) to the surface of the specimen equals the distance from the specimen to the focal plane of the ocular, or, in other words, the source of light should be approximately imaged on the sample. The mirror type of illuminator is not suitable for very short focus objectives (4 mm. or less), since it obscures a relatively large portion of the lens surface.

14. With objectives of the photographic type, vertical illumination is obtained by inserting the illuminator (plane glass) between the lens and the surface of the specimen. Oblique illumination may be obtained by directing the beam of light so that it strikes the surface of the specimen obliquely or, in a lesser degree, by rotating the reflector of the vertical illuminator.

15. For lenses of the photographic type of more than 48-mm. focal

length, the illumination is either diffused, for example, daylight; oblique, as obtained by a beam of light directed upon the specimen obliquely from one side; or "vertical." For the last, a large "vertical illuminator" (plane glass) between the lens and object is used. In order to increase the size of the field, which otherwise would be restricted in diameter to that of the photographic lens, a relatively large plano-convex lens should be placed between the reflecting plane-glass and the source of parallel light, the lens being located so that the *optical* distance between it and the photographic lens equals the focal length of the plano-convex lens. Moistening the surface of the specimen with water, glycerin or oil will sometimes be found to be desirable for the purpose of increasing the contrast in the photograph.

16. *Illumination of Fractured Specimens.*—A good reproduction of a fractured specimen may be readily obtained by using two sources of artificial light of unequal intensities, placed one on each side of the specimen. A reflector may be used to replace the weaker light source if desired. The second, or weaker illuminant serves to neutralize partially the deep shadows cast by the stronger one and so produces a good relief effect.

17. *Filters for Microscopy.*—Light filters may be used for any of the following purposes:

(*a*) For obtaining monochromatic (at least approximate) light. This is particularly desirable for achromatic lenses. Filters having a dominant wave length of 5500 Å. U. (*i. e.*, yellowish green) are very suitable for *general* use with such lenses, since most achromatic lenses being designated for visual rather than photographic purposes, are corrected for this portion of the spectrum.

(*b*) For increasing the contrast between various constituents—the color of the filter must, of course, be chosen according to the object to be examined.

(*c*) For lengthening the time of exposure in case of very brilliant illumination, thus avoiding the use of very small diaphragm openings.

(*d*) For taking advantage of the maximum resolving power of a lens, for example, in very high magnification, for which violet or blue filters are recommended.

IV. PHOTOGRAPHIC MATERIALS

18. *Plates.*—A medium-speed, that is, moderately fine-grained, photographic plate will be found very suitable for most photomicrographic work for showing details of structure.

If color sensitivity must be taken into account, a panchromatic (*i. e.*, sensitized for all colors) plate may be necessary, though for most

metallographic specimens one of the orthochromatic type (sensitive to yellow green in addition to the blue end of the spectrum) will usually be found to answer the purpose. For some purposes, "contrast" plates are desirable; this may be the case when there are but few structural details, for example, inclusions in a polished but unetched metallic matrix or for some low-magnification examinations.

19. *Paper.*—As a general rule, a printing paper with a glossy surface is desirable. The maximum gloss can be obtained by drying the prints on enameled or "ferro type" plates which have been previously brushed with a solution of paraffin wax in benzol or other solvent and then polished.

APPENDIX

RECOMMENDED PRACTICE FOR THE CARE OF THE EYES WHEN USING A METALLOGRAPHIC MICROSCOPE

All optical instruments of reputable make are so designed and optically corrected that there should be no discomfort to the user, if the eye is normal or corrected with proper spectacles and proper illumination is used, not forgetting that some eyes will bear brighter illumination than others.

In the microscopical examination of metals it is customary to use illuminants of high intensity to secure adequate illumination in photography. With the ordinary microscope or other optical instruments an illumination of 3 to 5 foot candles at the eyepiece is generally sufficient, and it should be in the examination of metals.

The carbon arc is a very bright light source and while desirable for photography, in order that the time of exposure of the photographic plate may be reduced as much as possible, is, nevertheless, dangerous for visual observation if not properly controlled. If a reduction of the illumination is made by means of diaphragms, it results in a reduction of the effective aperture of the objective and therefore the resolving power, that is, the ability of the objective to separate two closely situated points in the object. The back lens of the objective, when seen with the eyepiece removed, should be filled with light if full resolving power is desired.

Filters, placed between the light source and the vertical illuminator, as well as the colored glass cap fitting over the eyepiece, reduce the illumination and will generally be found sufficient for lamps such as the ribbon filament. If, however, an arc lamp is used, these filters will not be found to be sufficient to reduce the illumination for continuous observation, and if the outfit is so used a harmful blinding effect will be experienced. A remedy for this is by the use of filters of neutral smoke glass placed between the light source and the vertical illuminator.

Several degrees of density are advisable as specimens vary and observers vary in light sensitiveness. The darker filters will probably require the protection of a water cell as they absorb considerable heat and may break if unprotected.

For visual observation the illumination should be reduced to the lowest intensity that permits satisfactory results. Details appear to better advantage when glare is eliminated. If much visual work is to be done it would be advisable to have two interchangeable sources such as a ribbon filament for visual work and an arc lamp for photography.

It is the custom for trained observers with the microscope to keep both eyes open at all times. If one eye is closed a muscular strain is placed upon the eye in use. If one finds it difficult to keep both eyes open, an eyeshade may be placed before the unused eye. Such a shade may be made of cardboard, or a shade of hard rubber can be purchased for a nominal sum. Several metallurgists are using binocular eyepieces which permit the use of both eyes.

Observers who wear glasses, often remove them when using the microscope. If the defect in the eyes is limited to near or far sightedness, the deficiency may be corrected by focussing the microscope. If, however, the observer has astigmatism, a defect in which one meridian of the eye focuses at a different distance from another meridian, correction cannot be made by adjustment of the instrument. If the cylindrical power of one's spectacle lenses is one diopter or less, very little trouble will be experienced if the spectacles are not worn. Where greater cylindrical power is necessary, the spectacles should be worn or some other correction applied.

If it is found inconvenient to wear spectacles, owing to the difficulty in placing the eye at the eyepoint of the eyepiece, a cap containing a lens corresponding to the observer's prescription can be placed over the eyepiece. The axis of the cylinder should be plainly marked upon the cap and care used to place this axis in position upon the microscope as given in the oculist's prescription.

In conclusion, three cautions might be noted, as follows:

1. An illumination brighter than is necessary to make observations should not be used.

2. The unused eye should not be closed.

3. Spectacles should not be removed unless other means are provided for correcting the eye.

STANDARD DEFINITIONS OF TERMS RELATING TO METALLOGRAPHY[1]

Serial Designation: E 7 – 27

These definitions are issued under the fixed designation E 7; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1921; ADOPTED IN AMENDED FORM, 1924; REVISED, 1927.

Alloy.—A substance, having metallic properties, consisting of two or more metallic elements, or of metallic and non-metallic elements, which are miscible with each other when molten, and have not separated into distinct layers when solid.

NOTE.—Alloys when solid may be composed of eutectics, eutectoids, solid solutions, chemical compounds, or of aggregates of these components with each other or with pure metals. In the commercial sense, the term "alloy" would also include the case where some separation into distinct layers had occurred.

Alpha Brass.—A copper-zinc alloy with a copper content greater than approximately 64 per cent. It is composed of but one type of crystals all of which are of the same composition.

Beta Brass.—A copper-zinc alloy with a copper content of approximately 54 per cent, composed of but one type of crystals all of which are of the same composition.

NOTE.—At ordinary temperatures, the normal range of beta brass is from 51 to 55 per cent copper. Quenching from higher temperatures considerably broadens this range. Between 64 and 55 per cent copper, the copper-zinc alloys consist of mixed crystals of alpha and beta, the relative proportion of which depends upon the composition and heat treatment. Alloys of this type can be mechanically worked while hot and are frequently referred to as "Muntz Metal." When rapidly cooled from high temperatures (that is, from at or near the melting point) mixed alpha and beta may occur with copper as high as 70 per cent.

Etching Reagent.—A substance or reagent used to reveal the structure of a metal or alloy causing a difference in the appearance of different constituent parts or different grains.

NOTE.—This substance is usually a solution of the reagent in water, acid or alkali, but etching may in some cases be brought out by a differential oxidation produced by "heat tinting."

[1] Under the standardization procedure of the Society, these definitions are under the jurisdiction of the A.S.T.M. Committee E-4 on Metallography.

Equi-axed Grain.—A grain which has approximately equal dimensions in all directions.

NOTE.—This term is practically restricted to unstrained metals.

Grain.—A term used for an allotrimorphic crystal present in metals and in one-component alloys.

NOTE.—Although a crystal may show division by "twinning," etc., it is regarded as the grain rather than smaller sub-divisions. In the case of alloys of more than one component, the crystal which, by its transformation, gave rise to these constituents is taken as the grain when its limits are still discernible; if the limits are not discernible the individual constituents are considered as grains.

Grain Size.—This is preferably expressed as the number of grains per unit area of cross-section. The average cross-sectional area of the grain may also be given or the average dimensions. Grain size of strained material is expressed by the average number per linear unit in two directions, or by the average number per unit cross-sectional area, together with the ratio of length to breadth (L/B).

NOTE.—By the "Intercept" Method for grain count, the number of grains and fractions of grains along a line of known length on two axes at right angles to each other are counted. By the "Planimetric" Method for grain count, the number of grains and fractions of grains within a definite area are counted.

Intercept Method for Grain Count.—See note under Grain Size.

Macrograph.—A graphic reproduction of any object which has not been magnified more than 10 diameters.

NOTE.—When it is desired to indicate that it is a photographic reproduction, the term "photomacrograph" may be employed.

Magnification.—The ratio of the size of the image to that of the object.

NOTE.—Magnification is generally expressed in "diameters," thus "× 100" or "100 diameters."

Metal.—Any of the metallic elements, either of very high purity or of ordinary commercial grades.

NOTE.—Brass and many other alloys are metals in the commercial sense, but alloys in the scientific sense.

Metallography.—That branch of science which relates to the constitution and structure, and their relation to the properties, of metals and alloys.

Micrograph.—A graphic reproduction of any object magnified more than 10 diameters.

NOTE.—When it is desired to indicate that it is a photographic reproduction, the term "photomicrograph" may be employed.

Muntz Metal.—See note under *Beta Brass.*

Planimetric Method for Grain Count.—See note under Grain Size.

STANDARD SPECIFICATIONS
FOR
SIEVES FOR TESTING PURPOSES[1]

Serial Designation: E 11 – 26

These specifications are issued under the fixed designation E 11; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1925; ADOPTED, 1926.

Sieves for precision testing have a variety of uses, including both dry screening and wet screening of material. The primary object is to separate materials according to the size of particle. Since particles are three dimensional and the openings of screens are areas having two dimensions only, the method of separation by means of screens is at best an approximation. In many instances, however, it is the best practical means at hand, and will give useful and reliable results if care is taken in securing representative samples, in the preparation of the sample for testing, in the details of procedure and in the method of reporting results. In the Appendix are indicated those points which must be considered in specifying sieving tests for any individual material.

An essential in each method, however, is a series of sieves of known characteristics. The important consideration in sieves is the size of opening and with the size of opening known it is possible to translate the results obtained in one series of sieves into terms of another series. The importance of the size of opening in the sieve series covered by these specifications is emphasized by designating the sieves in terms of opening in microns. This new scheme of designation should accordingly cause no confusion, giving as it does a direct indication of the size of opening. As such, it is not open to the objections to the various arbitrary number designations heretofore in use and it is also free from the objection to the designation by means of mesh in that it is independent of the size of wire.

With the size of opening known, the method of recording results is simplified. It is recommended that in reporting sieve analyses in graphic form the sizes of sieve opening be arranged as ordinates with the largest size at the top and that the percentages be plotted as abscissas.

Scope.

1. These specifications cover sieves for use in the usual cases of precision testing for the fineness of materials (classification of materials according to size). The sieves have been designated according to the size of openings in terms of microns, the corresponding United States Standard Sieve Series designation in arbitrary numbers being given for the convenience of those familiar with the latter scheme of designation.

[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee E-1 on Methods of Testing.

PHYSICAL REQUIREMENTS

Cloth and Frame.

2. Wire cloth for standard sieves shall be woven (not twilled, except that the cloth of 44, 53 and 62-micron sieves may be twilled until further notice) from brass, bronze, or other suitable wire and mounted on the frames without distortion. To prevent the material

TABLE I.—REQUIREMENTS FOR SIEVE OPENINGS AND WIRE DIAMETERS WITH PERMISSIBLE VARIATIONS.

Designation	Corresponding U. S. Standard Sieve Series Number	Sieve Opening		Wire Diameter		Tolerance in Average Opening, per cent	Tolerance on Wire Diameter, per cent		Tolerance in Maximum Opening, per cent
		mm.	in.	mm.	in.		Under	Over	
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
4760 micron	4	4.76	0.187	1.27	0.050	±3	15	30	10
4000 "	5	4.00	0.157	1.12	0.044	±3	15	30	10
3360 "	6	3.36	0.132	1.02	0.040	±3	15	30	10
2830 "	7	2.83	0.111	0.92	0.036	±3	15	30	10
2380 "	8	2.38	0.0937	0.84	0.0331	±3	15	30	10
2000 "	10	2.00	0.0787	0.76	0.0299	±3	15	30	10
1680 "	12	1.68	0.0661	0.69	0.0272	±3	15	30	10
1410 "	14	1.41	0.0555	0.61	0.0240	±3	15	30	10
1190 "	16	1.19	0.0469	0.54	0.0213	±3	15	30	10
1000 "	18	1.00	0.0394	0.48	0.0189	±3	15	30	10
840 "	20	0.84	0.0331	0.42	0.0165	±5	15	30	25
710 "	25	0.71	0.0280	0.37	0.0146	±5	15	30	25
590 "	30	0.59	0.0232	0.33	0.0130	±5	15	30	25
500 "	35	0.50	0.0197	0.29	0.0114	±5	15	30	25
420 "	40	0.42	0.0165	0.25	0.0098	±5	15	30	25
350 "	45	0.35	0.0138	0.22	0.0087	±5	15	30	25
297 "	50	0.297	0.0117	0.188	0.0074	±6	15	35	40
250 "	60	0.250	0.0098	0.162	0.0064	±6	15	35	40
210 "	70	0.210	0.0083	0.140	0.0055	±6	15	35	40
177 "	80	0.177	0.0070	0.119	0.0047	±6	15	35	40
149 "	100	0.149	0.0059	0.102	0.0040	±6	15	35	40
125 "	120	0.125	0.0049	0.086	0.0034	±6	15	35	40
105 "	140	0.105	0.0041	0.074	0.0029	±8	15	35	60
88 "	170	0.088	0.0035	0.063	0.0025	±8	15	35	60
74 "	200	0.074	0.0029	0.053	0.0021	±8	15	35	60
62 "	230	0.062	0.0024	0.046	0.0018	±8	15	35	90
53 "	270	0.053	0.0021	0.041	0.0016	±8	15	35	90
44 "	325	0.044	0.0017	0.036	0.0014	±8	15	35	90

NOTE.—Screens having larger openings than those included in the table may be specified, but in specifying screens of larger openings the actual size of the opening (in millimeters or in inches) shall be stated. A tolerance of ±3 per cent on average openings and of 10 per cent in maximum openings shall be permitted.

being sieved from catching in the joint between the cloth and the frame, the joint shall be smoothly filled with solder, or so made that the material will not catch. The sieve frames should be circular, about 20 cm. (8 in.) in diameter and about 5 cm. (2 in.) or 2.5 cm. (1 in.) between the top of the frame and the cloth.

NOTE.—The size specified above is for the regular standard testing sieve, but for special purposes other sizes may be used, as for example, the 3-in. sieve which is designed especially for use on laboratory balances as in the testing of pigments.

Permissible Variations.

3. The average opening between the adjacent warp and the adjacent shoot wires, taken separately, shall be that given in column

3 (or 4) of Table I, within the "Tolerance in Average Opening" given in column 7. The average diameter of the warp and of the shoot wires, taken separately, of the cloth of any given sieve shall be that given in column 5 (or 6) of Table I within the "Tolerance on Wire Diameter" given in columns 8 and 9. The maximum opening between adjacent parallel wires shall not exceed the nominal width of opening for that sieve by more than the "Tolerance in Maximum Opening" given in column 10 of Table I.

WORKMANSHIP

Workmanship.

4. The sieves shall be free from imperfections in the sieve cloth or its mounting, as for example, punctured, loose or wavy cloth, imperfections in soldering, etc.

MARKING

Marking.

5. The sieves shall bear a label upon which the manufacturer's nominal opening in metric units (preferably in microns) with the equivalent in inches, together with the size of wire should be given.

NOTE.—It is recommended that, until the new micron designation shall have been thoroughly established, in addition the corresponding United States Standard Sieve Series number be given.

METHODS OF TESTING

Methods of Testing.

6. (*a*) To determine whether the cloth conforms to the requirements of these specifications, the wire diameter shall be measured in each direction by means of a micrometer-microscope or projection apparatus or other suitable apparatus of requisite precision, care being taken in all cases to avoid diffraction effects in measuring to the edge of a wire. Micrometer calipers and steel scales should not be used for this purpose. The mesh shall be determined by counting the number of openings for a distance of at least 6 in. in both directions of the sieve, using a scale, either glass or steel, and a microscope. The use of scales with special rulings for obtaining mesh by counting "interference bands" is recommended in cases where large numbers of any of the sieves with the smaller openings are to be measured. From the wire diameter and the mesh the average opening shall be computed.

NOTE.—No general rule can be given for the number of observations to be taken, except that they be sufficient to cause no change in the result if say 3 or 4 additional measurements are made.

(*b*) Measurements of large openings shall be made by means of the micrometer-microscope or the projection lantern or other suitable apparatus in the same way as wire diameters are measured.

NOTE.—In order to insure the securing of standard sieves it is possible to obtain from the manufacturer or dealer sieves which have been certified by the U. S. Bureau of Standards.

APPENDIX

LIST OF POINTS TO BE CONSIDERED IN DRAWING UP SPECIFICATIONS FOR A SIEVING TEST

I. APPARATUS.

1. Enumeration of sieves to be used.
2. Auxiliary apparatus required for collection and reduction of gross sample, sample containers, and apparatus other than the sieves used in making the tests.

II. SAMPLING.

1. Unit of sampling.
2. Method of collecting representative gross sample.
3. Size of gross sample.
4. Cautions to be taken in handling sample to prevent contamination or change.
5. Reduction of gross sample.

III. PREPARATION OF THE SAMPLE FOR TESTING.

1. Drying.
2. Mixing.
3. Special treatment, if any is necessary.
4. Selection of test portion.
5. Size of test portion.

IV. PROCEDURE.

A. Dry Screening:

1. Order in which the sieves are to be used.
2. Detailed description of method of shaking.
3. Detailed description of procedure other than method of shaking.
4. End point.

B. Wet Screening:

1. Liquid to be used.
2. Description of any preliminary separation by classification or other means.
3. Order in which screens are to be used.
4. Detailed description of procedure including amount and method of adding liquid, method of stirring or other agitation.
5. End point.

V. METHOD OF REPORTING RESULTS.

VI. ALLOWABLE VARIATIONS BETWEEN DUPLICATE TESTS ON THE SAME MATERIAL.

STANDARD METHODS OF VERIFICATION OF TESTING MACHINES[1]

Serial Designation: E 4 – 27

These methods are issued under the fixed designation E 4; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE 1923; ADOPTED IN AMENDED FORM, 1924; REVISED, 1927.

DEFINITIONS

Definitions.

1. (*a*) *Testing Machine.*—A mechanical device for applying a load (force) to a specimen.

NOTE.—Usually the magnitude of the load can be changed at the will of the operator. Many testing machines are arranged to measure the load, but this is not always the case, especially with impact machines and machines for testing ductility.

(*b*) *Error.*—In the case of a testing machine, the value obtained by subtracting the correct value of the quantity measured (usually load) from the indicated value as given by the testing machine.

NOTE.—The error may be positive or negative.

(*c*) *Percentage of Error.*—In the case of a testing machine, the ratio, expressed in per cent, of the error to the correct value of the quantity measured.

(*d*) *Correction.*—In the case of a testing machine, the value obtained by subtracting the indicated value from the correct value of the quantity measured.

NOTE.—The correction has the same magnitude as the error but the opposite sign.

It is recommended that, except for special cases, no corrections be used on machines tested and found to have errors within the tolerances given in these methods.

(*e*) *Tolerance.*—In the case of a testing machine, the maximum allowable error in the value of the quantity indicated.

[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee E-1 on Methods of Testing.

NOTE.—It is convenient to express tolerance in terms of percentage of error. The numerical value of the tolerance for a testing machine is so stated hereafter in these methods.

The word "accurate" applied to a testing machine shall be used without numerical values. The word "error" shall be used with numerical values. For example: "An accurate testing machine was used for the investigation"; but "The error of the testing machine at a load of 30,000 lb. was 15 lb." A testing machine is said to be accurate if the indicated load is within the specified tolerance of the actual load.

The *accuracy* of a testing machine should not be confused with *sensitiveness*. For example, a testing machine might be very sensitive—that is, it might indicate quickly and definitely small changes in the load—but, nevertheless, be very inaccurate. On the other hand, the accuracy of the results is, in general, limited by the sensibility.

(*f*) *Loading Range.*—In the case of a testing machine, the range of indicated loads for which the testing machine gives results within the specified tolerances. The loading range shall not include loads either greater than the largest load or less than the smallest load applied in verifying the testing machine.

METHODS FOR VERIFYING TESTING MACHINES THAT MEASURE LOAD

Direct Methods Recommended.

2. Wherever practicable, testing machines shall be verified by applying standard weights directly to the weighing mechanism of the testing machine, or by the use of standardized proving levers in connection with standard weights. The test loads selected shall be applied in both ascending and descending order, and the indications for both the ascending series and the descending series of loads shall be considered in the application of tolerances.

NOTE.—For machines in which the load-indicating device is actuated by a Bourdon pressure tube, a hydraulic (or steam-engine) indicator spring, or other device depending on the elastic properties of a material, the tolerances for the *descending* load shall be applied to differences in the indication for the corresponding ascending and descending readings. In such testing machines the test for ascending load shall be applied as rapidly as practicable after the testing machine has remained unloaded for at least six hours, and the time of applying the ascending series of loads shall not exceed thirty minutes. The descending load test shall be made after the maximum test load has remained on the machine for one hour, and the readings for descending loads shall be taken as rapidly as possible, and in any event the descending load test shall be completed within a period of twenty minutes.

Selection of Test Loads.

3. For any loading range, the testing machine shall be verified by at least four test loads. It is recommended that the test loads

used be 10, 20, 50, and 100 per cent of the maximum capacity at which the testing machine is to be used.

NOTE.—Where a large amount of testing of small specimens is to be done on a large capacity machine, it is recommended that the verification outlined above be supplemented by a series of smaller test loads selected in reference to the light work to be done on the testing machine.

(*A*) *Method of Verification by Standard Weights*

4. Standard metal weights of suitable design, finish, and adjustment shall be placed on the weighing platform of the testing machine or upon trays or other supports suspended from the load-measuring mechanism in place of the specimen. The weights shall be applied

Method by Standard Weights.

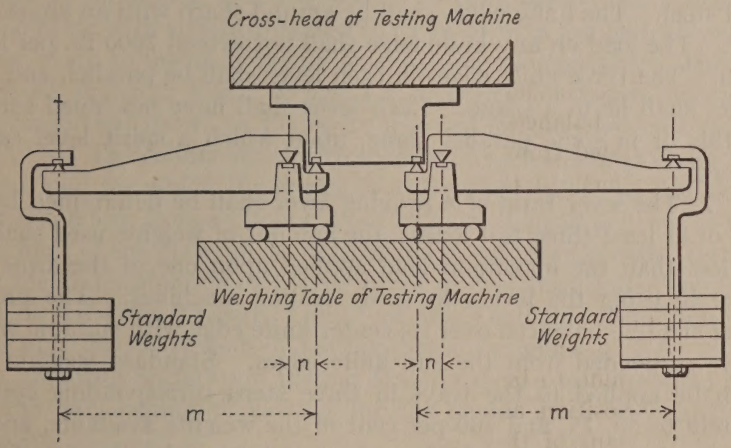

FIG. 1.—Proving Levers.

in increments and removed in the reverse order. They shall be arranged symmetrically with respect to the weighing platform, so that the center of gravity of the load lies in the vertical line through the center of the platform. The applied load and the indicated load shall be recorded for each test load applied, and the error computed from these data.

NOTE.—The method of verification by standard weights can be used only on vertical testing machines. The total load is limited by the size of the platform and the number of weights available. Often twenty weights of 50 lb. each are used, a total of 1000 lb.

This method of verification is seldom used for any but small testing machines, as the loading range does not include the loads for which large machines are used.

(*B*) *Method of Verification by Standardized Proving Levers*

Description of Levers.

5. The arrangement of proving levers for verifying testing machines is shown in Fig. 1. The two levers rest on supports on the weighing platform of the testing machine. These supports shall move easily in a horizontal direction, which insures that the forces at each of the knife edges shall be very nearly vertical. The inner knife edges in each lever bear against a suitable block in the movable head of the testing machine. Weight trays or hangers are suspended from each of the outer knife edges and these trays or hangers are loaded with standard weights. The increment of load put on the testing machine by the standard weights is the amount of standard weights multiplied by the lever ratio m/n, Fig. 1.

Specifications of Levers.

6. The knife edges, as well as their supports, shall be of hardened tool steel. The knife edges shall be ground sharp with an angle of 90 deg. The load on any knife edge shall not exceed 7000 lb. per linear inch. The three knife edges in each lever shall be parallel, and their edges shall lie in a plane. Each lever shall have machined surfaces in this or in some parallel plane, upon which a spirit level can be placed.

Verification of Levers.

7. The lever ratio of a proving lever shall be determined by the use of at least three test loads; the amount of weights used shall not be less than the maximum load applied upon one of the arms of a lever in using the levers to verify testing machines. The proving lever shall be balanced over its center knife edge with suitable weight trays suspended from the end knife edges. Standard weights shall then be applied to the trays in three steps, corresponding approximately to 50, 75, and 100 per cent of the weights available, and the proving lever shall then be brought to a balance by the use of small weights and by observations of the freely swinging proving lever. From the weights in the two weight trays the lever ratio shall be computed.

Method of Procedure.

8. The proving levers shall be placed symmetrically in the testing machine to be verified and both levers brought as near to a horizontal position as is feasible, after applying each increment of load, by means of the movable head of the testing machine. The testing machine shall be balanced with the levers in place and the weight trays empty. Standard weights shall be applied in increments, half an increment in each tray, and they shall be removed in the reverse order. The weights shall be placed symmetrically on the weight trays, with the center of gravity of the weights over the center of the tray. The applied load and the indicated load shall

be recorded for each test load applied, and the error computed from these data.

NOTE.—The method of verification by standardized proving levers is used, at the present time, only on vertical testing machines. It is often used up to loads of 10,000 lb.

(C) Method of Verification by Means of an Elastic Calibration Device

Method by Calibration Device.

9. In this method the testing machine to be verified is tested by comparing its load indications with the amount of elastic deformation of a calibration device, the deformation being measured with a delicate strainometer.

Calibration Device.

10. The calibration device may be a bar tested in tension or in compression or an elastic loop or other shape whose elastic deformation can be measured, and if a tension or compression bar is used it shall be fitted with spherical-seated shackles or with a spherical-seated bearing block to insure as nearly axial loading as is possible. The arrangement shown in Fig. 2 or Fig. 3 is suggested for tension bars and the arrangement shown in Fig. 4 is suggested for compression bars.

Adjustment of Calibration Device.

11. (*a*) The calibration device shall be of such size that under the greatest load for which the device is to be used (called its full load) the stress on any cross-section will not be more than 80 per cent of the elastic limit of the material, as determined in accordance with Method II for the Determination of Elastic Limit as described under the definition of the term "Elastic Limit" of the Tentative Definitions of Terms Relating to Methods of Testing (Serial Designation: E 6 – 25 T) of the American Society for Testing Materials[1] on a test specimen cut from the bar, forging or casting for the device after its final heat treatment.

(*b*) Before the calibration device is used for verification purposes, it shall be loaded to its full load at least six times, and between successive loadings it shall be heated to a temperature of 100° C. (212° F.) for a period of thirty minutes or shall be allowed to rest for a period of 24 hours. The object of this treatment is to adjust the device to its bearings and to relieve internal strain.

Loading Range.

12. The *loading range* of a calibration device is the range of indicated loads for which the device gives results within specified tolerances. Obviously, the loading range may not include loads either greater than the largest load or less than the smallest load applied in verifying the calibration device.

[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 25, Part I, p. 879 (1925); also 1927 Book of A.S.T.M. Tentative Standards, p. 744.

Method of Procedure.

13. (*a*) The loading range of a calibration device shall be determined by verifying its indications by the use of standard weights or by standard weights and proving levers. In verifying the indications of the device, an initial load of 1 per cent of its full load shall first be applied. All changes of strainometer reading and of applied load shall be reckoned from the readings at this initial load. Successive loads shall be applied, a recommended series of loads being 10, 20, 50

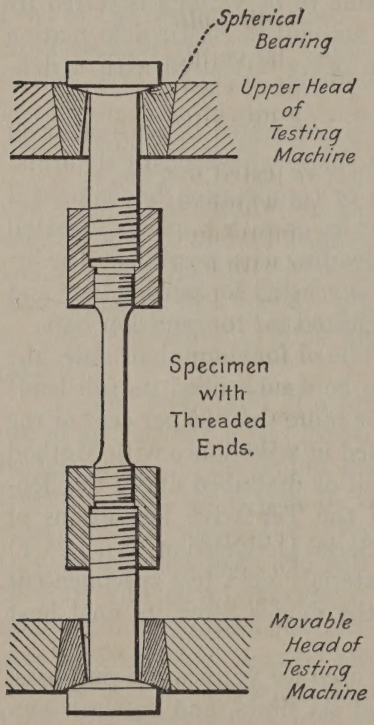

FIG. 2.

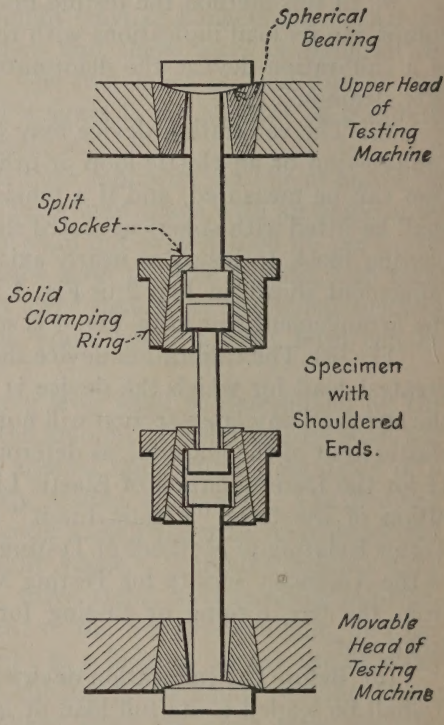

FIG. 3.

and 100 per cent of the full load of the device. Such a series shall be applied to the bar at least five times to determine the relation of applied load to strainometer reading, the shackles or bearing blocks being readjusted before each application of the series.

(*b*) The average of the five (or more) strainometer readings obtained in this way shall be taken for each load applied. The average of the differences (taken without regard to algebraic sign) between the individual strainometer readings for any load and the mean reading for that load constitutes the average deviation for that load. The lowest value of load for which the average deviation is not greater

than 0.5 per cent of the strain for that load is the lower limit of the loading range of the calibration device.

NOTE.—If in taking five or more strainometer readings for any load the deviation of any one reading is more than 1 per cent from the mean reading, then this series of five or more readings shall be repeated.

Strainometer.

14. The strainometer for elastic calibration devices which employ elastic bars in axial tension or axial compression shall be so designed as to indicate the average elongation or compression of the bar. For any elastic calibration device, it shall be sufficiently sensitive to indicate a change of 0.25 per cent of the minimum load in the loading range of the device. If the strainometer is not permanently attached to the calibration device, the strainometer shall be removed and replaced

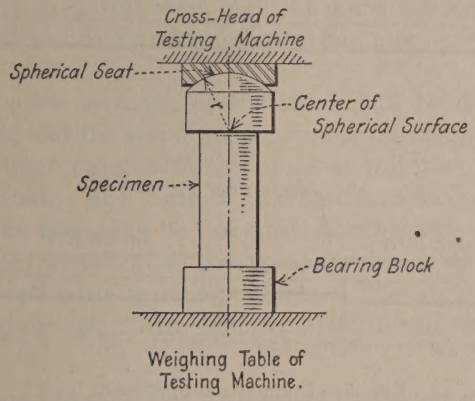

FIG. 4.

for each successive reading taken during the calibration of the device itself. This, of course, does not mean that the strainometer must be removed for each reading in the regular use of the instrument.

Precautions.

15. In using the calibration device it is important that just previous to taking any reading, including the initial reading of a series, there shall be no reversal in the direction of motion of the indicating mechanism of the strainometer, because such reversal may introduce error due to backlash in the instrument. That is, when taking readings for a series of increasing loads the load should be brought up to each predetermined test load, and when taking readings for a series of decreasing loads the load should be brought down to each predetermined test load.

Temperature Correction.

16. In using a calibration device made of steel, correction for variation in mean temperature during any calibrations made on different occasions should be made by allowing a diminution of 0.015

per cent ($\frac{15}{1000}$ of 1 per cent) in the modulus of elasticity of steel for each 1° F. increase in temperature. During any calibration with an elastic calibration device, temperature conditions should be kept as uniform as is possible.

(*D*) *Verification by Comparison Method*

Description of Comparison Method.

17. When the direct method of verification of a testing machine cannot be carried out (as is the case at present with horizontal testing machines, for example), or when an elastic calibration device is not available a comparison method of verification may be used. In this method the machine to be verified is tested by comparing its indications with the corresponding readings obtained under the same con-

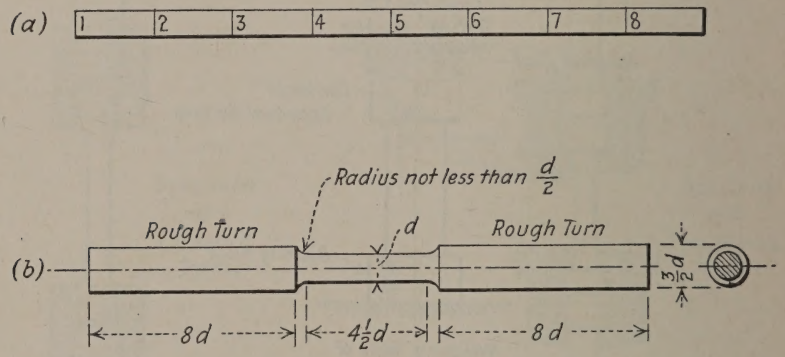

FIG. 5.—Comparison Specimen.
(*a*) Method of Numbering Specimens.
(*b*) Form of Test Specimen.

ditions by the use of another testing machine, especially tested and verified, as specified in Section 18. The method of verification by comparison shall be carried out by the use of a series of companion specimens, half of which are to be tested in tension in the machine to be verified, and half of which are to be tested in tension in the especially verified testing machine which serves as a standard machine. The general provisions respecting the application of the test loads and the loading range which are outlined in the direct method of verifying testing machines shall apply to the verification of testing machines by the comparison method, so far as is practicable.

NOTE.—The method of verification of a testing machine by standard weights (Section 4) and the method of verification by standardized proving levers (Sections 5 to 8) are both regarded as superior to the method of verification by the use of companion specimens. If the results of a verification test of a testing machine by the comparison method fail to agree with the results of a verification by either the

standard-weight method or the proving-lever method, the results of the verification by the comparison method shall be discarded.

Requirements for Testing Machines used for Verifying Other Machines.

18. (*a*) A testing machine which is to be used as the standard for verifying other testing machines shall itself be verified by a special test, in which the verification is carried out twice. The loading range shall be determined by the tolerance for new testing machines, namely, ±1 per cent (Section 22). For the loading range established, the differences in indications found in the two tests of the standard machine shall not exceed 0.25 per cent.

(*b*) In verifying testing machines by the comparison method, corrections shall be applied to the indications of the standard machine and these corrections shall be based on the average correction obtained in the two tests used in its verification.

Test Specimens.

19. (*a*) For each test load, eight or more tension test specimens shall be cut from soft rolled or drawn steel and numbered consecutively, as in Fig. 5 (*a*).

(*b*) The tensile strength of the steel shall be determined by a preliminary test and the sets of specimens for the comparison test shall have such nominal cross-sectional areas as will give, approximately, the loads required. The form of the specimen shall be as shown in Fig. 5 (*b*). The ends may be threaded, or otherwise machined, to fit holders, but it is recommended that those specimens shipped to another laboratory be left with cylindrical ends. The actual value of "*d*" (Fig. 5) for each specimen shall be determined by means of a micrometer.

NOTE.—It should be noted that the standard tension test specimen,[1] 0.5 in. in diameter and having a 2-in. gage length, satisfies the requirements for a specimen for the verification of a testing machine by the comparison method.

Method of Procedure.

20. (*a*) The specimens having odd numbers shall be tested in the machine to be verified and those having even numbers in the standard testing machine. The tensile strength only shall be determined.

(*b*) The speed of the testing machine, by which is meant the speed of the pulling head when the machine is running idle with no specimen in the machine, when testing verification specimens shall be approximately the same for both the standard testing machine and the machine being verified. The speed shall be the slowest speed that can be obtained on both machines; in any case the speed shall not exceed 1 in. per minute per inch of diameter of comparison specimen.

(*c*) When testing verification specimens, especial care shall be

[1] See p. 32, Fig. 1.

taken to maintain the weighing beam of the testing machine in equilibrium as the tensile strength of the specimen is approached. It is recommended that a mark be placed at the middle of the trig loop and that a pointer be placed on the beam for verification tests, and that the pointer be kept as nearly on the mark as possible.

Computation of Error.

21. (*a*) The average tensile strength (in pounds per square inch) of the odd-numbered specimens, multiplied by the nominal area of cross-section, shall be considered a measure of the indicated load, and the average tensile strength of the even-numbered specimens, multiplied by the nominal area of cross-section, shall be considered a measure of the applied load. The error shall be computed from these data.

(*b*) If the tensile strength (in pounds per square inch) of any verification specimen varies more than 1 per cent from the mean of the group with which it is tested, its tensile strength shall not be used in computing the error of the testing machine. If more than one specimen in the odd-numbered group or one in the even-numbered group exceeds the allowable variation in tensile strength, all the specimens shall be discarded and another set prepared.

TOLERANCES FOR TESTING MACHINES THAT MEASURE LOAD

Tolerances.

22. All testing machines that measure load shall conform to the following tolerances:[1]

(*a*) *New Machines.*—The error for loads in the loading range shall not exceed ±1.0 per cent for new machines or for those which have had any of the knife edges in the weighing mechanism repaired or renewed.

(*b*) *Used Machines.*—The error for loads in the loading range shall not exceed ±1.5 per cent.

Corrections.

23. The indicated load of a testing machine shall not be corrected either by computation or by the use of a calibration diagram to obtain values within the required tolerance.

TIME INTERVAL BETWEEN VERIFICATIONS

Time Interval Between Verifications.

24. It is recommended that testing machines, when in constant use, be verified at intervals of six months and, when used intermittently, at intervals of two or three years. Testing machines shall, however, be verified immediately after making repairs or adjust-

[1] It is believed that the tolerances given in this section may be made much smaller when more perfect methods of verification become generally available; and that the tolerances might well be materially reduced if there is available equipment for verifying testing machines by the use of standard weights (Section 4) or by the use of standardized proving levers (Sections 5 to 8).

ments of the weighing mechanism, and whenever there is reason to doubt the accuracy of the results, without regard to the time interval since the last verification.

REPORTS AND CERTIFICATES

25. A clear and complete report shall be prepared of each verification of a testing machine. This report shall contain all data necessary to verify the accuracy of the report, and shall be filed for future reference. This report shall state clearly the method of verification used. **Reports.**

26. A certificate giving the maker's serial number and a brief description of the testing machine, the maker's name, the date of verification, and the loading range, shall be signed by the person responsible for the maintenance of the testing machine, and this certificate shall be posted in plain view of a person operating the testing machine. **Certificates.**

STANDARD METHODS OF BRINELL HARDNESS TESTING OF METALLIC MATERIALS[1]

Serial Designation: E 10 – 27

These methods are issued under the fixed designation E 10; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1924; ADOPTED IN AMENDED FORM, 1927.

The Brinell test for determining the hardness of metallic materials consists in applying a known load to the surface of the material to be tested through a hardened steel ball of known diameter. The diameter (or depth) of the resulting permanent impression in the metal is measured. The Brinell hardness number is taken as the quotient of the applied load divided by the area of the surface of the impression, which is assumed to be spherical. If P is the applied load (measured in kilograms), D is the diameter of the steel ball (measured in millimeters) and d is the diameter of the impression (measured in millimeters), then:

$$\text{B.H.N.} = \frac{P}{\frac{\pi D}{2}\left(D - \sqrt{D^2 - d^2}\right)}$$

in which B.H.N. is the Brinell hardness number in kilograms per square millimeter.

If the steel ball were not deformed under the applied load and if the impression were truly spherical, then the above formula would be a general one, and any combination of applied load and size of ball could be used. As the impression is not quite a spherical surface (since there must always be some deformation of the steel ball and some recovery of form of the metal in the impression), for a standard Brinell test the size and characteristics of the ball and the magnitude of the applied load must be standardized. (A standard ball 10 mm. in diameter and a load of 3000 kg. for hard metals and 500 kg. for soft metals is standard practice. See Sections 3 and 6.

In Table I is given the Brinell hardness number corresponding to various diameters of impression for both 500 and 3000 kg. load, making it unnecessary to compute for each test the value of the Brinell Hardness Number by the above formula.

[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee E-1 on Methods of Testing.

These methods are in effect a revision of the Methods for Brinell Hardness Tests of the Standard Methods of Mechanical Testing of Metallic Materials. The standard methods, which were last published under the Serial Designation: E 1 – 18, have accordingly been withdrawn.

TABLE I.—BRINELL HARDNESS NUMBERS.

Steel Ball, 10 mm. in Diameter, Pressures of 500 and 3000 kg.

Prepared by the Engineering Mechanics Section, Bureau of Standards.

The values given in this table for hardness numbers are merely solutions of the equation given in the introductory paragraphs. They do not imply that Brinell tests are feasible on materials of a hardness indicated by the highest values in the table.

Diameter of Indentation, mm.	Brinell Hardness Number		Diameter of Indentation, mm.	Brinell Hardness Number		Diameter of Indentation, mm.	Brinell Hardness Number		Diameter of Indentation, mm.	Brinell Hardness Number		Diameter of Indentation, mm.	Brinell Hardness Number	
	500-kg. Load	3000-kg. Load		500-kg. Load	3000-kg. Load		500-kg. Load	3000-kg. Load		500-kg. Load	3000-kg. Load		500-kg. Load	3000-kg. Load
2.00	158	945	2.50	100	601	3.00	69.1	415	3.50	50.3	302	4.00	38 1	229
2.01	156	936	2.51	99 4	597	3.01	68.6	412	3.51	50.0	300	4 01	37.9	228
2.02	154	926	2.52	98 6	592	3.02	68.2	409	3.52	49.7	298	4 02	37 7	226
2.03	153	917	2.53	97 8	587	3.03	67.7	406	3 53	49.4	297	4.03	37 5	225
2.04	151	908	2.54	97.1	582	3.04	67 3	404	3.54	49.2	295	4.04	37 3	224
2.05	150	899	2.55	96.3	578	3.05	66 8	401	3.55	48.9	293	4.05	37.1	223
2.06	148	890	2 56	95.5	573	3.06	66.4	398	3.56	48.6	292	4.06	37.0	222
2.07	147	882	2.57	94 8	569	3.07	65.9	395	3.57	48 3	290	4.07	36 8	221
2.08	146	873	2 58	94 0	564	3.08	65 5	393	3.58	48.0	288	4.08	36.6	219
2.09	144	865	2.59	93.3	560	3.09	65.0	390	3.59	47.7	286	4.09	36.4	218
2.10	143	856	2.60	92.6	555	3.10	64.6	388	3.60	47.5	285	4.10	36.2	217
2.11	141	848	2.61	91.8	551	3.11	64.2	385	3.61	47.2	283	4.11	36.0	216
2.12	140	840	2.62	91.1	547	3.12	63.8	383	3.62	46.9	282	4.12	35.8	215
2.13	139	832	2.63	90.4	543	3.13	63 3	380	3.63	46.7	280	4.13	35.7	214
2.14	137	824	2.64	89.7	538	3.14	62.9	378	3.64	46.4	278	4.14	35.5	213
2.15	136	817	2.65	89.0	534	3.15	62.5	375	3.65	46.1	277	4.15	35.3	212
2.16	135	809	2.66	88.4	530	3.16	62.1	373	3.66	45.9	275	4 16	35.1	211
2.17	134	802	2 67	87 7	526	3.17	61.7	370	3.67	45.6	274	4.17	34 9	210
2.18	132	794	2.68	87.0	522	3.18	61.3	368	3.68	45.4	272	4.18	34.8	209
2.19	131	787	2.69	86.4	518	3.19	60.9	366	3.69	45.1	271	4.19	34.6	208
2.20	130	780	2.70	85.7	514	3.20	60.5	363	3.70	44.9	269	4.20	34.4	207
2.21	129	772	2.71	85.1	510	3.21	60.1	361	3.71	44.6	268	4.21	34.2	205
2.22	128	765	2.72	84.4	507	3.22	59 8	359	3.72	44.4	266	4.22	34.1	204
2.23	126	758	2.73	83.8	503	3.23	59.4	356	3.73	44.1	265	4.23	33.9	203
2.24	125	752	2.74	83.2	499	3.24	59.0	354	3.74	43.9	263	4.24	33.7	202
2.25	124	745	2.75	82.6	495	3.25	58.6	352	3.75	43.6	262	4.25	33.6	201
2.26	123	738	2.76	81.9	492	3.26	58.3	350	3.76	43.4	260	4.26	33.4	200
2.27	122	732	2.77	81.3	488	3.27	57.9	347	3.77	43.1	259	4.27	33.2	199
2.28	121	725	2.78	80.8	485	3.28	57.5	345	3 78	42.9	257	4.28	33.1	198
2.29	120	719	2.79	80.2	481	3.29	57.2	343	3.79	42.7	256	4.29	32.9	198
2.30	119	712	2.80	79.6	477	3.30	56.8	341	3.80	42.4	255	4.30	32.8	197
2.31	118	706	2.81	79.0	474	3.31	56.5	339	3.81	42.2	253	4.31	32.6	196
2.32	117	700	2.82	78.4	471	3.32	56.1	337	3.82	42.0	252	4.32	32.4	195
2.33	116	694	2.83	77.9	467	3.33	55.8	335	3.83	41.7	250	4.33	32.3	194
2.34	115	688	2.84	77.3	464	3.34	55.4	333	3.84	41.5	249	4.34	32.1	193
2.35	114	682	2.85	76.8	461	3.35	55.1	331	3.85	41.3	248	4.35	32.0	192
2.36	113	676	2.86	76.2	457	3.36	54.8	329	3.86	41.1	246	4.36	31.8	191
2.37	112	670	2.87	75.7	454	3.37	54.4	326	3.87	40.9	245	4.37	31.7	190
2.38	111	665	2.88	75.1	451	3.38	54.1	325	3.88	40.6	244	4.38	31.5	189
2.39	110	659	2.89	74.6	448	3.39	53.8	323	3.89	40.4	242	4.39	31.4	188
2.40	109	653	2.90	74.1	444	3.40	53 4	321	3.90	40.2	241	4.40	31.2	187
2.41	108	648	2.91	73 6	441	3.41	53.1	319	3.91	40.0	240	4.41	31.1	186
2.42	107	643	2.92	73.0	438	3.42	52.8	317	3.92	39.8	239	4.42	30.9	185
2.43	106	637	2.93	72.5	435	3.43	52.5	315	3.93	39.6	237	4.43	30.8	185
2.44	105	632	2.94	72.0	432	3.44	52.2	313	3.94	39.4	236	4.44	30.6	184
2.45	104	627	2.95	71.5	429	3.45	51.8	311	3 95	39.1	235	4 45	30.5	183
2.46	104	621	2.96	71.0	426	3.46	51.5	309	3 96	38.9	234	4.46	30.3	182
2.47	103	616	2.97	70.5	423	3.47	51.2	307	3.97	38.7	232	4.47	30.2	181
2.48	102	611	2.98	70.1	420	3.48	50.9	306	3.98	38.5	231	4.48	30.0	180
2.49	101	606	2.99	69.6	417	3.49	50.6	304	3.99	38.3	230	4.49	29.9	179

TABLE I—(*Continued*).

Diameter of Indentation, mm.	Brinell Hardness Number		Diameter of Indentation, mm.	Brinell Hardness Number		Diameter of Indentation, mm.	Brinell Hardness Number		Diameter of Indentation, mm.	Brinell Hardness Number		Diameter of Indentation, mm.	Brinell Hardness Number	
	500-kg. Load	3000-kg. Load		500-kg. Load	3000-kg. Load		500-kg. Load	3000-kg. Load		500-kg. Load	3000-kg. Load		500-kg. Load	3000-kg. Load
4.50	29 8	179	5.00	23.8	143	5.50	19.3	116	6.00	15.9	95.5	6.50	13.3	79.6
4.51	29.6	178	5.01	23.7	142	5.51	19.2	115	6.01	15.9	95.1	6.51	13.2	79.3
4.52	29.5	177	5.02	23.6	141	5.52	19.2	115	6.02	15.8	94.8	6.52	13.2	79.0
4.53	29.3	176	5.03	23.5	141	5.53	19.1	114	6.03	15.7	94.4	6.53	13.1	78.7
4.54	29.2	175	5.04	23.4	140	5.54	19.0	114	6.04	15.7	94.1	6.54	13.1	78.4
4.55	29.1	174	5.05	23.3	140	5.55	18.9	114	6.05	15.6	93.7	6.55	13.0	78.2
4.56	28.9	174	5.06	23.2	139	5.56	18.9	113	6.06	15.6	93.4	6.56	13.0	77.9
4.57	28 8	173	5.07	23.1	138	5.57	18.8	113	6.07	15.5	93.0	6.57	12.9	77.6
4.58	28.7	172	5.08	23.0	138	5.58	18.7	112	6.08	15.4	92.7	6.58	12.9	77.3
4.59	28.5	171	5.09	22.9	137	5.59	18.6	112	6.09	15.4	92.3	6.59	12.8	77.1
4.60	28.4	170	5.10	22.8	137	5.60	18.6	111	6.10	15.3	92.0	6.60	12.8	76.8
4.61	28.3	170	5.11	22.7	136	5.61	18.5	111	6.11	15.3	91.7	6.61	12.8	76.5
4.62	28.1	169	5.12	22.6	135	5.62	18.4	110	6.12	15.2	91.3	6.62	12.7	76.2
4.63	28.0	168	5.13	22.5	135	5.63	18.3	110	6.13	15.2	91.0	6.63	12.7	76.0
4.64	27.9	167	5.14	22.4	134	5.64	18.3	110	6.14	15.1	90.6	6.64	12.6	75.7
4.65	27.8	167	5.15	22.3	134	5.65	18.2	109	6.15	15.1	90.3	6.65	12.6	75.4
4.66	27.6	166	5.16	22.2	133	5.66	18.1	109	6.16	15.0	90.0	6.66	12.5	75.2
4.67	27.5	165	5.17	22.1	133	5.67	18.1	108	6.17	14.9	89.6	6.67	12.5	74.9
4.68	27.4	164	5.18	22.0	132	5.68	18.0	108	6.18	14.9	89.3	6.68	12.4	74.7
4.69	27.3	164	5.19	21.9	132	5.69	17.9	107	6.19	14.8	89.0	6.69	12.4	74.4
4.70	27.1	163	5.20	21.8	131	5.70	17.8	107	6.20	14.8	88.7	6.70	12.4	74.1
4.71	27.0	162	5.21	21.7	130	5.71	17.8	107	6.21	14.7	88.3	6.71	12.3	73.9
4.72	26.9	161	5.22	21.6	130	5.72	17.7	106	6.22	14.7	88.0	6.72	12.3	73.6
4.73	26.8	161	5.23	21.6	129	5.73	17.6	106	6.23	14.6	87.7	6.73	12.2	73.4
4.74	26.6	160	5.24	21.5	129	5.74	17.6	105	6.24	14.6	87.4	6.74	12.2	73.1
4.75	26.5	159	5.25	21.4	128	5.75	17.5	105	6.25	14.5	87.1	6.75	12.1	72.8
4.76	26.4	158	5.26	21.3	128	5.76	17.4	105	6.26	14.5	86.7	6.76	12.1	72.6
4.77	26.3	158	5.27	21.2	127	5.77	17.4	104	6.27	14.4	86.4	6.77	12.1	72.3
4.78	26.2	157	5.28	21.1	127	5.78	17.3	104	6.28	14.4	86.1	6.78	12.0	72.1
4.79	26.1	156	5.29	21.0	126	5.79	17.2	103	6.29	14.3	85.8	6.79	12.0	71.8
4.80	25.9	156	5.30	20.9	126	5.80	17.2	103	6.30	14.2	85.5	6.80	11.9	71.6
4.81	25.8	155	5.31	20.9	125	5.81	17.1	103	6.31	14.2	85.2	6.81	11.9	71.3
4.82	25.7	154	5.32	20.8	125	5.82	17.0	102	6.32	14.1	84.9	6.82	11.8	71.1
4.83	25.6	154	5.33	20.7	124	5.83	17.0	102	6.33	14.1	84.6	6.83	11.8	70.8
4.84	25.5	153	5.34	20.6	124	5.84	16.9	101	6.34	14.0	84.3	6.84	11.8	70.6
4.85	25.4	152	5.35	20.5	123	5.85	16.8	101	6.35	14.0	84.0	6.85	11.7	70.4
4.86	25.3	152	5.36	20.4	123	5.86	16.8	101	6.36	13.9	83.7	6.86	11.7	70.1
4.87	25.1	151	5.37	20.3	122	5.87	16.7	100	6.37	13.9	83.4	6.87	11.6	69.9
4.88	25.0	150	5.38	20.3	122	5.88	16.7	99.9	6.38	13.8	83.1	6.88	11.6	69.6
4.89	24.9	150	5.39	20.2	121	5.89	16.6	99.5	6.39	13.8	82.8	6.89	11.6	69.4
4.90	24.8	149	5.40	20.1	121	5.90	16.5	99.2	6.40	13.7	82.5	6.90	11.5	69.2
4.91	24.7	148	5.41	20.0	120	5.91	16.5	98.8	6.41	13.7	82.2	6.91	11.5	68.9
4.92	24.6	148	5.42	19.9	120	5.92	16.4	98.4	6.42	13.6	81.9	6.92	11.4	68.7
4.93	24.5	147	5.43	19.9	119	5.93	16.3	98.0	6.43	13.6	81.6	6.93	11.4	68.4
4.94	24.4	146	5.44	19.8	119	5.94	16.3	97.7	6.44	13.5	81.3	6.94	11.4	68.2
4.95	24.3	146	5.45	19.7	118	5.95	16.2	97.3	6.45	13.5	81.0	6.95	11.3	68.0
4.96	24.2	145	5.46	19.6	118	5.96	16.2	96.9	6.46	13.4	80.7	6.96	11.3	67.7
4.97	24.1	144	5.47	19.5	117	5.97	16.1	96.6	6.47	13.4	80.4	6.97	11.3	67.5
4.98	24.0	144	5.48	19.5	117	5.98	16.0	96.2	6.48	13.4	80.1	6.98	11.2	67.3
4.99	23.9	143	5.49	19.4	116	5.99	16.0	95.9	6.49	13.3	79.8	6.99	11.2	67.0

APPARATUS

Micrometer Microscope.

1. The divisions on the micrometer scale of the microscope or other measuring device used for the measurement of the diameter of impression shall be such as to permit the direct measuring of the diameter to 0.1 mm. and the estimation of the diameter to 0.01 mm.

Brinell Ball.

2. (*a*) The balls used in Brinell hardness testing shall be of hardened steel or other equally hard material.

(*b*) A ball to be suitable for use shall not show a permanent change in diameter greater than 0.0025 mm. (0.0001 in.) when pressed with a force of 3000 kg. against a piece of steel having a Brinell hardness number of 500 or greater.[1]

(*c*) If a ball is used in a test of a specimen which shows a Brinell hardness number greater than 500, the ball shall be remeasured after the test. Should the ball show a permanent change in diameter greater than that permitted in Paragraph (*b*), the ball shall be unsuitable for further use in a standard test.[1]

Size of Standard Ball.

3. The standard ball for Brinell hardness testing shall be 10 mm. (0.3937 in.) in diameter with a deviation from this value of not more than 0.01 mm. (0.0004 in.) in any diameter, but the diameter of any ball measured at various points shall be constant within a tolerance of ±0.0025 mm. (0.0001 in.).

For testing very small specimens or very thin specimens it is sometimes necessary to make Brinell hardness tests with a ball less than 10 mm. in diameter. For such tests (which are not to be regarded as standard Brinell tests) the relation between applied load, P, measured in kilograms, and diameter of ball, D, measured in millimeters, should be:

$$P = 3000 \frac{D^2}{10^2} = 30\ D^2 \text{ for iron and steel;}$$

and $$P = 500 \frac{D^2}{10^2} = 5\ D^2 \text{ for brass, bronze and soft metals in general.}$$

For extremely soft metals the relation $P = D^2$ may be used.

Balls differing in size from the standard 10-mm. ball shall conform to the requirements for the material and the tolerance in size of diameter as specified for the standard ball.

TEST SPECIMENS

Specimens used in Brinell hardness testing vary greatly in form since it is frequently desirable to make the impression upon a part to be used in the finished product rather than upon a sample test specimen.

Thickness of Specimen.

4. The thickness of the piece tested shall be such that no bulge or other marking showing the effect of the load appears on the side of

[1] In testing softer metals, it is not, of course, necessary to have balls of this extreme hardness. However, a ball to be suitable for use should withstand pressure against the hardest material to be tested without showing a permanent change in diameter greater than 0.0025 mm.

the piece opposite the impression. In any event the thickness of the specimen shall be at least 10 times the depth of impression.

Finish of Specimen.

5. The surface on which the impression is to be made shall be filed, ground, machined, or polished with emery paper so that the edge of the impression shall be clearly enough defined to permit of the measurement of the diameter within 0.01 mm. (0.0004 in.).

APPLICATION AND MAGNITUDE OF LOAD

Magnitude.

6. The load in the standard Brinell test shall be 3000 kg. for iron and steel and 500 kg. for brass, bronze and soft metals generally.

NOTE.—For extremely soft metals a load of 100 kg. is sometimes used. If for any reason it is necessary to use loads differing from those specified above, the load used should be specifically stated in the test report, conveniently as a subscript of the hardness numeral.

Application.

7. (*a*) The load shall be applied steadily to the specimen without jerk.

(*b*) The load shall be applied for at least 10 seconds in the case of iron and steel and for at least 30 seconds in the case of other metals.[1]

(*c*) The center line of the applied load shall be far enough from any edge of the specimen so that when a straight-edge is applied to the edge after the load has been applied, the eye can detect no bulge in the edge due to the load and the resulting impression.

MEASUREMENT OF IMPRESSION

8. In the standard Brinell hardness test the diameter of the impression shall be measured.

Measurement of Diameter of Impression.

9. When a micrometer microscope is used to measure the diameter of the impression the sharpness of definition of the edge of the impression can be increased by the use of a movable lamp for illuminating the specimen, placing the lamp so that the contrast of light and shade will bring first one edge of the impression, then the other into sharp definition. In testing very hard material, the sharpness of definition of the impression can be somewhat increased by the use of a ball lightly etched with nitric acid, or by the use of some pigment, such as Prussian blue, on the ball. In testing material in which there is considerable recovery of shape, the material may first be coated with a dull black pigment, such as drawing ink or a mixture of graphite and alcohol. The edge of the impression is rendered clear on a surface so coated.

[1] It was suggested in discussion that for magnesium and magnesium alloys the minimum time of application be 2 minutes. It was also suggested that for any given soft metal a definite time for holding the load be specified rather than a minimum time. See discussion of the Report of Committee E-1, *Proceedings*, Am. Soc. Testing Mats., Vol. 24, Part I, pp. 729 and 730 (1924).

BRINELL HARDNESS TESTS IN WHICH DEPTH OF IMPRESSION IS MEASURED IN PLACE OF DIAMETER

When it is necessary to make Brinell hardness tests very rapidly, as is sometimes the case when the Brinell test is used as a control test for the output of a heat-treating furnace, the depth of impression under load, or after the release of load, can be measured more expeditiously than the diameter of impression. The depth of impression is usually determined from the relative motion of the plunger carrying the ball and the specimen. This method of determining Brinell hardness is not to be regarded as a standard method, and when requirements of speed necessitate its use, the Brinell hardness number should not be determined from the geometrical relation of depth of impression to diameter, based on the assumption that the impression has a spherical surface. In such tests the relation between the Brinell hardness number and depth of impression may be determined with a fair degree of accuracy from tests on specimens of material of different degrees of hardness, several impressions being made on each specimen, and the depth under load, or the depth on release of load, and the diameter of impression after release of load being measured for each impression. By the use of a diagram or by interpolation, a table giving the Brinell hardness number for a given depth of impression can be prepared.

CALIBRATION OF BRINELL HARDNESS TESTING APPARATUS

Load-Measuring Device.

10. A load-measuring device which is in common use for Brinell hardness testing machines involves the measurement of fluid pressure on a piston of known diameter, working in a cylinder with so perfect a fit that packing is not necessary. To this piston is attached the ball. Other load-measuring devices use combinations of weights and levers. The use of dead weights acting on a small piston is to be preferred to the ordinary Bourdon gage for measuring the intensity of fluid pressure.

Methods of Calibration.

11. The load-measuring device of a Brinell hardness testing machine may be calibrated by the use of dead weights, or by the use of dead weights and proving levers or by an elastic calibration device or spring, in the manner described in the Standard Methods of Verification of Testing Machines (Serial Designation: E 4) of the American Society for Testing Materials.[1]

12. The load-measuring device of a Brinell hardness testing machine may be calibrated by making a series of impressions on specimens of different degrees of hardness, measuring the diameters of the impressions, making a second series of impressions by the use of any standardized testing machine and standard steel ball, and, using the same measuring device as for the first series of impressions, measuring the diameters of this second series of impressions. The error of the

[1] See p. 793. See also J. L. Jones and C. H. Marshall, "A New Method for Calibrating Brinell Hardness Testing Machines," *Proceedings*, Am. Soc. Testing Mats., Vol. XX, Part II, p. 392 (1920).

machine under calibration can be determined by the relative average values of the hardness numbers determined by its use and by the use of the standardized testing machine.

Specimen.

13. When the above companion-impression method of calibrating a Brinell hardness testing machine is used it is recommended that the specimens used be approximately 1 by 1 by 12 in. in size, and that specimens with as wide a range of hardness as is feasible be used. It is recommended that impressions made by the machine under calibration be spaced about 2.5 in. apart along the specimen, and that the impressions made by the standardized testing machine be spaced alternately along the length of the specimen with the impressions made by the machine under calibration.

Accuracy.

14. If any determination of hardness, either for the machine under calibration or for the standard machine differs by more than 2 per cent from the mean of the four determinations made with that machine it is recommended that such determination be discarded. If two determinations differ more than 2 per cent from the mean the whole series should be discarded.

Loading Range.

15. A Brinell hardness testing machine is acceptable for use over a loading range within which its load-measuring device is correct within 3 per cent.

Calibration of Micrometer Microscope.

16. The micrometer microscope or other device for measuring diameter of impression may be calibrated by using it to measure lengths on a standard steel or glass scale. The eye piece of a micrometer microscope should be adjusted so that throughout the range covered the error of reading does not exceed 0.01 mm.

STANDARD DEFINITIONS OF TERMS RELATING TO SPECIFIC GRAVITY[1]

Serial Designation: E 12 – 27

These definitions are issued under the fixed designation E 12; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1925; ADOPTED IN AMENDED FORM, 1927.

1. *Absolute Specific Gravity* (of solids and liquids).—The ratio of the weight referred to vacuum of a given volume of the material at a stated temperature to the weight referred to vacuum of an equal volume of gas-free distilled water[2] at a stated temperature. It shall be stated thus:

(*a*) When the temperatures of the material and of the water are the *same:*

Absolute Specific Gravity $x°$ C., ...,

where x is the temperature of the material and the water.

(*b*) When the temperatures of the material and of the water are *not the same:*

$$\text{Absolute Specific Gravity } \frac{x° \text{ C.}}{y° \text{ C.}} \text{ .....,}$$

where x is the temperature of the material and y the temperature of the water.

NOTE.—In the interest of standardization and simplification, the first form of statement of specific gravity (*a*) should be employed wherever practicable.

2. *Specific Gravity* (of solids and liquids).—The ratio of the weight in air of a given volume of the material at a stated temperature to the weight in air of an equal volume of distilled water at a stated temperature. It shall be stated thus:

(*a*) When the temperatures of the material and of the water are the *same:*

Specific Gravity $x°$ C., ...,

where x is the temperature of the material and the water.

[1] Under the standardization procedure of the Society, these definitions are under the jurisdiction of the A.S.T.M. Committee E-8 on Nomenclature and Definitions.

[2] Distilled water boiled vigorously in vacuum.

(*b*) When the temperatures of the material and of the water are *not the same:*

$$\text{Specific Gravity } \frac{x^\circ \text{ C.}}{y^\circ \text{ C.}} \text{ .....},$$

where x is the temperature of the material and y is the temperature of the water.

NOTE.—In the interest of standardization and simplification, the first form of statement of specific gravity (*a*) should be employed wherever practicable.

3. *Apparent Specific Gravity* (of solids).—The ratio of the weight in air of a given volume of the impermeable portion of a permeable material (that is, the solid matter including its impermeable pores or voids) at a stated temperature to the weight in air of an equal volume of distilled water at a stated temperature. It shall be stated thus:

(*a*) When the temperatures of the material and of the water are the *same:*

Apparent Specific Gravity x° C., ...,

where x is the temperature of the material and the water.

(*b*) When the temperatures of the material and of the water are *not the same:*

$$\text{Apparent Specific Gravity } \frac{x^\circ \text{ C.}}{y^\circ \text{ C.}} \text{ .....},$$

where x is the temperature of the material and y is the temperature of the water.

NOTE 1.—In scientific circles, specific gravity and density determinations made in air (that is, uncorrected to vacuum) are frequently distinguished by the adjective "apparent." Thus, the specific gravity defined by definition No. 2 would be designated as "apparent specific gravity" and that defined by definition No. 1 as "specific gravity." But in industry, the terminology is more generally in accordance with that given in these definitions.

NOTE 2.—The terms "permeable" and "impermeable" cannot be rigidly defined for general application. The exact meaning in a particular application is the conventional one inferred by the procedure specified for determining the specific gravity of the material in question.

NOTE 3.—In the interest of standardization and simplification, the first form of statement of specific gravity (*a*) should be employed wherever practicable.

4. *Bulk Specific Gravity* (of solids).—The ratio of the weight in air of a given volume of a permeable material (including both permeable and impermeable voids normal to the material) at a stated temperature to the weight in air of an equal volume of distilled water at a stated temperature. It shall be stated thus:

(*a*) When the temperatures of the material and of the water are the *same:*

Bulk Specific Gravity $x°$ C., ...,

where x is the temperature of the material and the water.

(*b*) When the temperatures of the material and of the water are *not the same:*

Bulk Specific Gravity $\frac{x° \text{ C.}}{y° \text{ C.}}$ .....,

where x is the temperature of the material and y is the temperature of the water.

NOTE 1.—See Note 2 under "Apparent Specific Gravity."

NOTE 2.—In the interest of standardization and simplification, the first form of statement of specific gravity (*a*) should be employed wherever practicable.

REGULATIONS GOVERNING STANDING COMMITTEES

ADOPTED, 1910; LATEST REVISION, 1927.

NOTE.—By action of the Executive Committee on January 6, 1912, the responsibility for the general Regulations Governing Standing Committees is vested in the Executive Committee and Committee E-5 on Standing Committees, with the understanding (1) that a proposed change in these Regulations originating with Committee E-5 shall be subject to approval by the Executive Committee of the Society; (2) that the Executive Committee of the Society shall make no changes in these Regulations without first referring the same to Committee E-5; and (3) that proposed changes in these Regulations thus adopted shall be announced in the next circular to members and become effective from the date of issue of that circular.

I. ORGANIZATION OF STANDING COMMITTEES

1. Creation.—The creation of a standing committee shall be subject to the authorization of the Executive Committee, acting either on a recommendation adopted by majority vote at an annual meeting of the Society, or on its own initiative.

2. Appointments and Classifications.—Appointments on standing committees shall be made by the Executive Committee subject to the following provisions:

(*a*) On committees dealing with subjects having a commercial bearing, the members of the committee shall be classified into "producers," "consumers," and "general interests," defined as follows:

Producers.—Those directly concerned in the production and sale of the commodity involved;

Consumers.—Those that use the commodity involved but are not directly concerned with its production and sale;

General Interests.—Independent engineers, educators and persons who are neither consumers nor producers as defined above.

On such committees either an equal numeric balance shall be maintained between the producers on the one hand, and the consumers and general interests, jointly, on the other hand; or the consumers and general interests may be allowed to predominate by majority vote of the producers.

(*b*) The classification of the members of a committee into producers, consumers, and general interests shall be left to each committee, subject to the following provisions, and with the understanding that a member dissatisfied with this classification has the right of appeal to the Executive Committee:

(1) A member who stands in the relation of producer to any product within the province of the committee shall be classed as a producer, although at the request of the officers of the committee concerned,

attention shall be called to the status of such members in a footnote worded as follows:

These members of Committee....., classed as Producers, stand in the relation of Producers to certain products, and in that of Consumers (or General Interests) to other products within the province of the committee.

(2) A nominally unattached expert, who is permanently retained by producing interests in the field of activities of the committee with which he is connected, shall be classed as a producer. The qualification "permanently retained" is to be understood to mean that the expert receives a regular monthly or yearly retainer from one or more producing interests under an indefinitely continuing arrangement.

(*c*) As a general policy, only one individual connected with a given firm, company, corporation, laboratory, or other institution shall be eligible to membership on a given committee, although exceptions to this rule may be permitted at the discretion of the committee concerned. In case two or more members of a committee are connected with the same firm, company, corporation, laboratory, or other institution, they shall, when a division is demanded, jointly command only a single vote.

(*d*) Additional appointments on existing committees shall be made only on the recommendation of, or with the approval of, such committees.

(*e*) Only members of the Society shall be eligible, in general, to appointment on committees, although exceptions may be authorized by the Executive Committee in favor of representatives of government branches or other societies.

3. Preliminary Organization.—The President of the Society will appoint the chairman *pro tem.* of a new committee from among the consumers or general interests. The chairman *pro tem.*, after communicating with the other members of the committee, will fix the place and time of the first meeting. He may, at his discretion, appoint one or more members of the committee to prepare material in advance for consideration at that meeting or he may prepare such material himself. This procedure is recommended as calculated to economize time at the meeting and to afford a definite basis for discussion.

4. Permanent Organization.—At the first meeting of a committee a permanent organization shall be effected by the election of a permanent chairman from among the consumers or general interests, and such other officers as the committee may desire, and the creation of such sub-committees as may be desired. The duties and powers assigned to these officers and sub-committees, and the details of management and administration in general, shall be at the discretion of each committee, subject to the limitations of these Regulations.

II. DIRECTIONS FOR CONDUCT OF BUSINESS

5. Meetings.—The meetings of standing committees and sub-committees shall be open only to their own members and to such visitors whose proposed invitation has been approved by the chairman.

Minutes of meetings of standing committees shall be kept and copies thereof shall regularly be sent to the Secretary-Treasurer of the Society.

6. Proxies.—A member of a standing committee shall be authorized to delegate any desired individual as his proxy with voting power, or without voting power if so specified; but no individual shall have more than one vote at a meeting of a committee.

7. Election of Officers.—Every standing committee shall hold an election of officers at or before the annual meeting of the Society occurring in the even years. The result of such election shall be included in the report of the committee for that year. The term of office of every officer shall be two years and officers shall be eligible for re-election.

8. Resignations.—Proposed resignations from office or from membership on a standing committee shall be reported directly to the chairman or the secretary of the committee concerned, and the result of any action taken in such matters shall be reported to the Secretary-Treasurer of the Society.

9. Sub-Committees.—Sub-committees shall have no standing in the Society except through their parent committees. Sub-committees on proposed complete standard specifications for materials shall consist of not fewer than six members, and at least one-half of the membership shall be composed of consumers and general interests. Departures from this requirement for exceptional reasons may be authorized by the Executive Committee.

III. STANDARDS AND RECOMMENDED PRACTICE

10. Standards.—"The term 'Standards' shall be applied collectively to (*a*) standard specifications, (*b*) standard methods, and (*c*) standard definitions."[1]

(*a*) The term "Standard Specifications" shall be applied to specifications designed to govern the purchase of materials. Such specifications may or may not include reference to tests, but they shall include limits for physical, chemical or other properties.

(*b*) The term "Standard Methods" shall be applied to methods of testing, analysis, sampling and similar operations. Standard Methods shall not include limits for physical, chemical or other properties.

(*c*) The term "Standard Definitions" is self-explanatory.

11. Tentative Standards.—The term "Tentative Standards" shall be applied to proposed standards which are published in the Proceedings for one or more years with a view of eliciting criticism, of which the committee concerned will take due cognizance before recommending final action toward their adoption as standard.

12. Recommended Practice.—"The term 'Recommended Practice' shall be applied to processes and methods not ordinarily subject to contract between purchaser and manufacturer."[1]

13. Matters of Engineering Design.—In the preparation of proposed standards the consideration of matters of engineering design or construction shall not in general be regarded as falling within the province of the Society. If, however, it should appear to a given committee that the consideration of

[1] Quoted from By-laws, Article VI, Section 1.

such matters is, for special reasons, indispensable in specifications designed to cover the customary relations between the producers and consumers of a given product, then reference to such matter in proposed specifications for that product shall be permitted within the scope necessary for the particular purpose above stated. Proposed standards embodying features of the character in question shall be submitted by the committee concerned to the Executive Committee for consideration and comment not later than the quarterly meeting immediately preceding the annual meeting at which the proposed standards are to be presented.

14. Preparation of Standards.—Proposed new standards or proposed amendments of existing standards shall originate in the particular committee within whose province such standards properly belong. No action affecting standards shall be taken by any standing committee except at meetings called for that purpose. Action at such meetings shall be subject to a two-thirds vote of those voting, and subsequently to a two-thirds vote of those voting on letter ballot of the entire committee. The results of each letter ballot as to the number of affirmative votes, the number of negative votes, and the number of members not voting, shall be announced in the report of the committee to the Society.

Dissenting members shall have the right to present minority reports, individually or jointly, at the annual meeting of the Society at which the majority report is presented.

15. Procedure Governing the Adoption of Standards.—Any recommendations affecting standards presented by the appropriate committees at the annual meeting of the Society shall be subject to the following provisions in Article VI, Section 1, of the By-laws:

"Proposed new standards shall be presented at an annual meeting, at which they may be amended by a two-thirds vote of those voting. On two-thirds vote of those voting, they shall be printed, as presented or as amended, in the Proceedings and separately under the title 'Tentative Standards,' on which written discussions addressed to the appropriate committee shall be invited. At the next annual meeting tentative standards shall be subject to amendment by a two-thirds vote of those voting. They may then be referred, by a like vote, to letter ballot of the Society, in which case a two-thirds vote of those voting shall be required for adoption; or, on the recommendation of the committee concerned, they may be continued as tentative, as printed or as amended, in which case the above prescribed procedures shall apply at any succeeding annual meeting.

"Proposed amendments of existing standards shall be presented at an annual meeting, at which they may be amended by a two-thirds vote of those voting. On two-thirds vote of those voting they shall be printed, as presented or as amended, in the Proceedings as part of the report of the appropriate committee; and collectively under the same cover with the Tentative Standards for that year. At any succeeding annual meeting they shall be subject to amendment by a two-thirds vote of those voting; and at the annual meeting in the year in which the book of A.S.T.M. Standards will next be published, they shall be subject to reference by a like vote to letter ballot of the Society, in which case a two-thirds vote of those voting shall be required for adoption.[1]

[1] *Interpretation.*—The Executive Committee and Committee E-5 on Standing Committees have ruled that proposed revisions of amendments that have previously been accepted for publication as tentative must be germane to the original amendment in order to come under this provision. Revisions that are not germane to the original amendments shall be considered as new amendments.

"The above requirement by which final action on proposed new standards or proposed amendments of existing standards shall be deferred for one or more years may, for exceptional reasons, be waived by a nine-tenths vote of those voting at the annual meeting at which they are first presented. In that case the above prescribed vote as to amendments, as to reference to letter ballot, and as to adoption shall remain unaffected."

"The above requirements governing action on proposed new standards or proposed amendments of existing standards shall be applicable also to proposed Recommended Practice."

16. Standards Involving Patents.—"Reports, resolutions and recommendations pertaining to or involving the use, or proposed use, in a standard or tentative standard, of any device or process which forms the subject matter of any existing patent, shall first be submitted to the Executive Committee, and shall be submitted to the Society only with the approval of the Executive Committee."[1]

Rulings.—The Executive Committee has adopted the following policies as applicable to standards involving patents:

Applying to the specifying of patented apparatus in A.S.T.M. Standards:

Where a standing committee desires to include in a standard of the Society the use of a patented instrument, appliance or machine for testing, for which the committee has written certain specifications, and where this instrument, appliance or machine is the only one specified in the standard, the Executive Committee will approve its inclusion in the standard provided the owner of the patent will execute a satisfactory agreement with the Society to license any reputable manufacturer approved by the Executive Committee to manufacture such instruments, appliances or machines for testing in accordance with the specifications of the Society.

Where the patented instrument, appliance or machine concerned is one of several alternative instruments that may be used in applying the standard of the Society, the other instruments not being patented, the Executive Committee will permit reference to such patented instrument without requiring the execution of an agreement such as above outlined, in the belief that the interests of the user of the standard are fully protected against an undesirable patent monopoly in that he can use other unpatented instruments in accordance with the provisions of the standard.

Applying to standards involving patented materials or patented processes:

The Executive Committee will consider upon their respective merits any proposals from the standing committees of the Society that specifications be prepared involving patented materials or patented processes. If such specifications are adopted by the Society, the Society does not undertake to insure any one utilizing such specifications against liability for infringement of any patent or assume any such liability, and such adoption does not constitute a recommendation of any patented or proprietary application that may be involved.

IV. REPORTS OF STANDING COMMITTEES

17. Reports.—The reports of standing committees shall be presented at the annual meetings. The report of every sub-committee shall be made to the parent committee and not to the Society direct. If such a report is embodied

[1] Quoted from By-laws, Article VI, Section 2.

wholly or in part in the report of the parent committee to the Society, the latter shall make definite references to such features in its own report and recommendations, if any, based thereon.

Standing committees shall include in their annual reports, in concise form, a statement of the essential facts regarding the origin of all proposed new standards and the reasons for proposing amendments in existing standards and tentative standards. Appropriate data respecting new methods of test or proposed modifications of existing methods of test shall be included in such annual reports or filed with Committee E-1 on Methods of Testing, as may seem preferable. Reference to available publications shall be accepted as appropriate data.

Standing committees shall include in their annual reports, or in a formal statement to the Executive Committee of the Society in case there is no report for a given year, their reasons for continuing a tentative standard or tentative revision of an existing standard in the tentative status for more than three years without revision or without recommendation for advancement to standard.

The results of letter ballot votes of the committee on actions affecting standards shall be announced in the report of the committee (see Section 14).

The report of a standing committee, before its presentation at the annual meeting, shall first have been submitted to letter ballot of the committee and shall have received the approval of at least two-thirds of those voting.

A statement of the following form shall appear at the close of every committee report:

> This report has been submitted to letter ballot of the committee which consists of ..... members; ..... members returned their ballots, of whom ..... have voted affirmatively, ... negatively, and ..... have marked their ballots "not voting."

Dissenting members shall have the right to present minority reports individually or jointly.

18. Advance Distribution of Reports.—The annual reports of the standing committees shall be transmitted to the Secretary-Treasurer of the Society as early in the calendar year as possible and not less than eight weeks in advance of the date of the annual meeting. Preprints of these reports shall be mailed by the Secretary-Treasurer to every member of the Society who has signified his desire to receive such reports, at the earliest possible subsequent date and not less than four weeks before the annual meeting, so that members may come to the meeting prepared to discuss such reports and that members not intending to be present at the meeting may contribute discussions by letter.

V. COOPERATION WITH COMMITTEES OF OTHER BODIES

19. Methods of Initiating Cooperation.—A standing committee desiring to cooperate with committees of other bodies on like or cognate subjects, or to bring about the appointment of similar committees by other bodies for purposes of cooperation, shall address a recommendation to that effect to the Executive Committee and, on the approval of the latter, negotiations to the desired end shall be conducted by the Secretary-Treasurer of the Society. Such cooperative relations shall entail no conditions at variance with these Regulations, and shall impose no restrictions upon the free and independent action of the standing committee.

20. Regulations Governing Cooperative Relations.

While ample opportunity is afforded for the standing committees of the Society to cooperate with other organizations through the formation of joint committees under suitable regulations, the whole question of cooperative work between societies has been in such a state of flux during recent years that it has been deemed unwise to endeavor to supply the subject matter of Section 20 of these Regulations.

Accordingly this section is temporarily left blank in anticipation of supplying its contents later.

VI. PUBLICATIONS

21. Publications.—Committees shall have no right to issue matter for publication through other than the regular Society channels, unless so authorized, for exceptional reasons, by the Executive Committee.

VII. EXPENSES OF STANDING COMMITTEES

22. Current Expenses.—Expenses for postage incurred in connection with the business of committees will be refunded by the Secretary-Treasurer of the Society on vouchers approved by the chairmen of these committees.

23. Stationery.—Correspondence relating to the business of committees or sub-committees shall be conducted on official stationery which will be furnished by the Secretary-Treasurer of the Society.

24. Extraordinary Expenses.—Expenses for items other than postage will not be assumed by the Society, unless such expenditures were incurred in pursuance of previous authorization of the Executive Committee, on recommendation of the chairman of the committee concerned, and within amounts specifically fixed by the Executive Committee.

25. Special Funds.—Committees engaged on subjects having a commercial bearing shall be authorized to solicit contributions from manufacturers towards research funds. Contributions from consumers to funds for this and other purposes shall be solicited only by the Executive Committee. All funds thus collected shall be transmitted to the Secretary-Treasurer of the Society and deposited by him in bank and placed to the credit of the committees on the books of the Society, subject to disbursement only on voucher signed by the chairman of the committee concerned.

26. Salaries and Fees.—Committees shall not be authorized to pay salaries or professional fees in any form to any of their officers or members. Assistants in connection with research work may be engaged at salaries or special compensation fixed by the committees concerned, provided that funds for such salaries or compensations shall previously have been deposited with the Secretary-Treasurer of the Society. Payments for such purposes shall be made by the Secretary-Treasurer of the Society only on vouchers approved by the chairman of the committee concerned.

VIII. DISCHARGE OF STANDING COMMITTEES

27. Discharge of Standing Committees.—Standing committees may be discharged by the Executive Committee, either at their own request or with their consent, on the completion of the work for which they were appointed, or in consequence of protracted inactivity. A standing committee which fails to present a report at three successive annual meetings of the Society will be required to show cause, in a written communication to the Executive Committee, why it should not be discharged.

Standing committees may be discharged for cause by the Executive Committee at its own initiative.

IX. METHODS AND INSTRUMENTS OF TESTING

28. Methods and Instruments of Testing.—Regulations Governing Methods and Instruments of Testing, adopted jointly by Committee E-5 on Standing Committees and the Executive Committee and made effective June 22, 1921, form part of the Regulations Governing Standing Committees. These regulations establish the responsibility of the standing committees for the preparation of methods of testing and the examination, design and recommendation of instruments for testing, as well as the authority of Committee E-1 on Methods of Testing and the relation between the standing committees and Committee E-1.[1]

X. NOMENCLATURE AND DEFINITIONS

29. Nomenclature and Definitions.—Regulations Governing Nomenclature and Definitions, adopted jointly by Committee E-5 on Standing Committees and the Executive Committee and made effective June 22, 1921, form part of the Regulations Governing Standing Committees. These regulations establish the responsibility of the standing committees for the preparation of nomenclature and definitions, as well as the authority of Committee E-8 on Nomenclature and Definitions and the relation between the standing committees and Committee E-8.[2]

COOPERATIVE POSSIBILITIES BETWEEN U. S. GOVERNMENT BRANCHES AND A.S.T.M. STANDING COMMITTEES

The basis on which various government branches may cooperate with the committees of this Society is indicated in the 1927 Year Book, pages 333–334. Any committee desiring to establish such cooperative relations shall address a recommendation to that effect to the Executive Committee, and on approval by the latter, negotiations to the desired end shall be conducted by the Secretary-Treasurer of the Society.

SUPPLEMENTARY REGULATIONS GOVERNING STANDING COMMITTEES

The standing committees of the Society may adopt supplementary regulations governing their various activities. Such regulations have been adopted by a number of committees of the Society.

[1] These regulations appear in the 1927 Year Book, p. 325.

[2] These regulations appear in the 1927 Year Book, p. 329.

LIST OF A.S.T.M. STANDARDS

As of September 1, 1927. Total Number, 340.

Published collectively in their latest revised form in 1927 BOOK OF A.S.T.M. STANDARDS—Parts I and II

These Standards are all copyrighted in the name of the American Society for Testing Materials. Permission to reprint any of these Standards can be obtained only from the Executive Committee on application to the Secretary-Treasurer.

The designations A 1, A 2, etc., of the Standards are fixed; the final numbers 14, 24, etc., indicate the year of adoption as standard or, in the case of revision, the year of last revision. The serial designations of Standards, which have for any reason been discontinued, are permanently dropped. In ordering Standards, the complete serial designations should be stated, thus, A 1 – 27, A 2 – 27, etc.

The standards are grouped according to the materials to which they apply. Duplicate listings appear in italics.

A. FERROUS METALS

STEEL

Standard Specifications

Steel Rails and Accessories.

A 1 – 27. For Open-Hearth Carbon-Steel Rails.
A 2 – 27. For the Manufacture of Open-Hearth Steel Girder Rails of Plain, Grooved and Guard Types.
A 3 – 24. For Low-Carbon-Steel Splice Bars.
A 4 – 14. For Medium-Carbon-Steel Splice Bars.
A 5 – 14. For High-Carbon-Steel Splice Bars.
A 6 – 14. For Extra-High-Carbon-Steel Splice Bars.
A 49 – 21. For Quenched High-Carbon-Steel Splice Bars.
A 76 – 27. For Low-Carbon-Steel Track Bolts.
A 50 – 24. For Quenched Carbon-Steel Track Bolts.
A 51 – 21. For Quenched Alloy-Steel Track Bolts.
A 65 – 24. For Steel Track Spikes.
A 66 – 21. For Steel Screw Spikes.

Structural Steel.

A 7 – 24. For Structural Steel for Bridges.
A 8 – 24. For Structural Nickel Steel.
A 94 – 27. For Structural Silicon Steel.
A 9 – 24. For Structural Steel for Buildings.
A 10 – 24. For Structural Steel for Locomotives.
A 11 – 24. For Structural Steel for Cars.
A 12 – 21. For Structural Steel for Ships.
A 13 – 24. For Rivet Steel for Ships.

Boiler Steels.

A 30 – 24. For Boiler and Firebox Steel for Locomotives.
A 70 – 27. For Boiler and Firebox Steel for Stationary Service.
A 31 – 24. For Boiler Rivet Steel.

Steel for Welding.

A 78 – 27. For Steel Plates of Structural Quality for Forge Welding.
A 89 – 27. For Steel Plates of Flange Quality for Forge Welding.

Concrete Reinforcement Steel.

A 15 – 14. For Billet-Steel Concrete Reinforcement Bars.
A 16 – 14. For Rail-Steel Concrete Reinforcement Bars.
A 82 – 27. For Cold-Drawn Steel Wire for Concrete Reinforcement.

Bar Steels.

A 107 – 27. For Commercial Quality Hot-Rolled Bar Steels.
A 108 – 27. For Commercial Cold-Finished Bar Steels and Cold-Finished Shafting.

Spring Steel and Springs.

A 14 – 27. For Carbon-Steel Bars for Railway Springs.
A 68 – 27. For Carbon-Steel Bars for Railway Springs with Special Silicon Requirements.
A 58 – 27. For Carbon-Steel Bars for Vehicle and General Purpose Springs.
A 59 – 27. For Silico-Manganese-Steel Bars for Railway Springs.
A 60 – 27. For Chrome-Vanadium-Steel Bars for Railway Springs.
A 61 – 16. For Helical Steel Springs for Railways.
A 62 – 16. For Elliptical Steel Springs for Railways.

Steel Blooms, Forgings and Axles.

*A 17 – 21. For Carbon-Steel and Alloy-Steel Blooms, Billets and Slabs for Forgings.
A 18 – 27. For Carbon-Steel and Alloy-Steel Forgings.
A 19 – 27. For Quenched-and-Tempered Carbon-Steel Axles, Shafts, and Other Forgings for Locomotives and Cars.
A 63 – 27. For Quenched-and-Tempered Alloy-Steel Axles, Shafts, and Other Forgings for Locomotives and Cars.
A 20 – 27. For Carbon-Steel Forgings for Locomotives.
A 21 – 27. For Carbon-Steel Car and Tender Axles.
A 22 – 21. For Cold-Rolled Steel Axles.

* Approved as "Tentative American Standard" by the American Engineering Standards Committee.

Steel Chain.

A 56 – 24. For Iron and Steel Chain.

Steel Wheels and Tires.

A 25 – 24. For Wrought Solid Carbon-Steel Wheels for Electric Railway Service.
A 57 – 24. For Wrought Solid Carbon-Steel Wheels for Steam Railway Service.
A 26 – 16. For Steel Tires.

Steel Castings.

A 27 – 24. For Steel Castings.
A 87 – 27. For Carbon-Steel Castings for Railroads.

Steel Tubes and Pipe.

A 83 – 27. For Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler Tubes.
A 53 – 27. For Welded and Seamless Steel Pipe.

Tool Steels.

A 71 – 26. For Carbon Tool Steel.
A 92 – 26. For High-Speed Tool Steel.

Steel for High-Temperature Service.

A 96 – 27. For Alloy-Steel Bolting Material for High-Temperature Service.

Zinc-Coated Sheets.

A 93 – 27. For Zinc-Coated (Galvanized) Sheets.

STANDARD METHODS

A 33 – 24. Of Chemical Analysis of Plain Carbon Steel.
A 55 – 24. Of Chemical Analysis of Alloy Steels.
A 90 – 24. Of Determining Weight of Coating on Zinc-Coated Articles.
A 91 – 24. Of Determining Weight of Coating on Tin, Terne, and Lead-Coated Sheets.
A 34 – 27. Of Test for Magnetic Properties of Iron and Steel.
E 3 – 24. Of Metallographic Testing of Iron and Steel.
E 10 – 27. Of Brinell Hardness Testing of Metallic Materials.

RECOMMENDED PRACTICES

A 35 – 24. For Annealing of Miscellaneous Rolled and Forged Carbon-Steel Objects.
A 36 – 24. For Heat Treatment of Carbon-Steel Castings.
A 37 – 27. For Carburizing and Heat Treatment of Carburized Objects.

WROUGHT IRON

STANDARD SPECIFICATIONS

A 72 – 27. For Welded Wrought-Iron Pipe.
A 83 – 27. *For Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler Tubes.*
A 84 – 27. For Staybolt, Engine-Bolt and Extra-Refined Wrought-Iron Bars.
A 86 – 27. For Hollow Rolled Staybolt Iron.
*A 41 – 18. For Refined Wrought-Iron Bars.
A 85 – 27. For Common Iron Bars.
*A 42 – 18. For Wrought-Iron Plates.
A 73 – 24. For Wrought-Iron Rolled or Forged Blooms and Forgings for Locomotives and Cars.
A 56 – 24. For Iron and Steel Chain.

STANDARD DEFINITIONS

A 81 – 27. Of Terms Relating to Wrought-Iron Specifications.

PIG IRON, CAST IRON, AND FINISHED CASTINGS

STANDARD SPECIFICATIONS

A 43 – 24. For Foundry Pig Iron.
A 44 – 04. For Cast-Iron Pipe and Special Castings.
A 74 – 18. For Cast-Iron Soil Pipe and Fittings.
A 45 – 14. For Cast-Iron Locomotive Cylinders.
A 46 – 24. For Chilled Cast-Iron Wheels.
A 47 – 27. For Malleable Castings.
A 48 – 18. For Gray-Iron Castings.
A 88 – 24. For High-Test Gray-Iron Castings.

STANDARD METHODS

A 64 – 27. Of Sampling and Chemical Analysis of Pig and Cast Iron.

FERRO-ALLOYS

STANDARD SPECIFICATIONS

A 97 – 27. For Tungsten Powder.
A 98 – 27. For Spiegeleisen.
A 99 – 27. For Ferro-Manganese.
A 100 – 27. For Ferro-Silicon.
A 101 – 27. For Ferro-Chromium.
A 102 – 27. For Ferro-Vanadium.

STANDARD METHODS

A 103 – 27. Of Sampling Ferro-Alloys.
A 104 – 27. Of Chemical Analysis of Ferro-Alloys.

* Approved as "Tentative American Standard" by the American Engineering Standards Committee.

B. NON-FERROUS METALS

STANDARD SPECIFICATIONS

Ingot Copper.

B 4 – 27. For Lake Copper Wire Bars, Cakes, Slabs, Billets, Ingots, and Ingot Bars.
B 5 – 27. For Electrolytic Copper Wire Bars, Cakes, Slabs, Billets, Ingots, and Ingot Bars.

Spelter.

B 6 – 18. For Spelter.

Lead.

B 29 – 23. For Pig Lead.

Nickel.

B 39 – 22. For Nickel.

Aluminum.

B 37 – 26. For Aluminum for Use in the Manufacture of Iron and Steel.

Deoxidizers.

B 51 – 27. For Phosphor Tin.
B 52 – 27. For Phosphor Copper.
B 53 – 27. For Silicon Copper.

Wire and Cable.

B 49 – 26. For Hot-Rolled Copper Rods for Wire Drawing.
B 1 – 27. For Hard-Drawn Copper Wire.
B 2 – 27. Medium Hard-Drawn Copper Wire.
B 3 – 27. For Soft or Annealed Copper Wire.
B 33 – 21. For Tinned Soft or Annealed Copper Wire for Rubber Insulation.
B 48 – 27. For Soft Rectangular Copper Wire.
B 8 – 27. For Bare Concentric-Lay Copper Cable: Hard, Medium-Hard, or Soft.
B 47 – 27. For Round and Grooved Hard-Drawn Copper Trolley Wire.

Bronze.

B 10 – 18. For the Alloy: Copper, 88 per cent; Tin, 10 per cent; Zinc, 2 per cent.
*B 30 – 22. For Brass Ingot Metal, Graded and Ungraded, for Sand Castings.
B 31 – 21. For Bronze Bearing Metal in Ingot Form.
B 22 – 21. For Bronze Bearing Metals for Turntables and Movable Railroad Bridges.
B 7 – 27. For Manganese-Bronze Ingots for Sand Castings.
B 54 – 27. For Manganese-Bronze Sand Castings.

* Approved as "Tentative American Standard" by the American Engineering Standards Committee.

White Metal.

*B 32 – 21. For Solder Metal.
B 23 – 26. For White Metal Bearing Alloys (known commercially as "Babbitt Metal").

Copper and Brass Plates, Tubes, Rods, etc.

B 11 – 18. For Copper Plates for Locomotive Fireboxes.
B 12 – 21. For Copper Bars for Locomotive Staybolts.
B 13 – 18. For Seamless Copper Boiler Tubes.
B 14 – 18. For Seamless Brass Boiler Tubes.
B 44 – 24. For Seamless Admiralty Condenser Tubes and Ferrule Stock.
B 55 – 25. For Seamless 70–30 Brass Condenser Tubes and Ferrule Stock.
B 56 – 25. For Seamless Muntz Metal Condenser Tubes and Ferrule Stock.
B 57 – 27. For Muntz Metal Condenser Tube Plates.
B 42 – 24. For Copper Pipe, Standard Sizes.
B 43 – 24. For Brass Pipe, Standard Sizes.
*B 15 – 18. For Brass Forging Rod.
*B 16 – 18. For Free-Cutting Brass Rod for Use in Screw Machines.
B 19 – 19. For Cartridge Brass.
B 20 – 19. For Cartridge Brass Disks.
B 21 – 27. For Naval Brass Rods for Structural Purposes.
B 36 – 27. For Sheet High Brass.

STANDARD METHODS

*B 34 – 20. Of Battery Assay of Copper.
B 35 – 24. Of Chemical Analysis of Pig Lead.
B 38 – 21. Of Chemical Analysis of Spelter.
B 41 – 23. Of Chemical Analysis of Nickel.
*B 18 – 21. Of Chemical Analysis of Alloys of Lead, Tin, Antimony and Copper.
*B 27 – 19. Of Chemical Analysis of Manganese Bronze.
*B 28 – 19. Of Chemical Analysis of Gun Metal.
B 45 – 27. Of Chemical Analysis of Brass Ingots and Sand Castings.
B 46 – 27. Of Chemical Analysis of Bronze Bearing Metal.
A 90 – 24. Of Determining Weight of Coating on Zinc-Coated Articles.
A 91 – 24. Of Determining Weight of Coating on Tin, Terne, and Lead-Coated Sheets.
E 5 – 27. Of Metallographic Testing of Non-Ferrous Metals and Alloys.
E 10 – 27. Of Brinell Hardness Testing of Metallic Materials.

C. CEMENT, LIME, GYPSUM, CONCRETE, AND CLAY PRODUCTS

CEMENT

STANDARD SPECIFICATIONS

C 9 – 26. Specifications and Tests for Portland Cement.
C 10 – 09. For Natural Cement.

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* Approved as "Tentative American Standard" by the American Engineering Standards Committee.

LIME

STANDARD SPECIFICATIONS

C 5 – 26. For Quicklime for Structural Purposes.
C 6 – 24. For Hydrated Lime for Structural Purposes.
C 45 – 25. For Quicklime and Hydrated Lime for Use in the Cooking of Rags for the Manufacture of Paper.
C 46 – 27. For Quicklime for Use in the Manufacture of Sulfite Pulp.
C 47 – 27. For Hydrated Lime for the Manufacture of Varnish.
C 48 – 24. For Quicklime and Hydrated Lime for Use in the Textile Industry.
C 49 – 24. For Quicklime and Hydrated Lime for the Manufacture of Silica Brick.
C 53 – 27. For Quicklime for Use in Water Treatment.
C 54 – 27. For Hydrated Lime for Use in Water Treatment.

STANDARD METHODS

C 50 – 27. Of Sampling, Inspection, Packing and Marking of Quicklime and Lime Products.

GYPSUM

STANDARD SPECIFICATIONS

C 22 – 25. For Gypsum.
C 23 – 22. For Calcined Gypsum.
C 28 – 27. For Gypsum Plasters.
C 35 – 25. For Gypsum Plastering Sand.
C 36 – 25. For Gypsum Wall Board.
C 37 – 25. For Gypsum Plaster Board.
C 52 – 27. For Gypsum Partition Tile or Block.

STANDARD METHODS

C 26 – 27. Of Testing Gypsum and Gypsum Products.

STANDARD DEFINITIONS

C 11 – 26. Of Terms Relating to the Gypsum Industry.

CONCRETE AND CONCRETE AGGREGATES

STANDARD SPECIFICATIONS

D 57 – 20. For Materials for Cement Grout Filler for Brick and Stone Block Pavements.
D 58 – 24. For Materials for Cement Mortar Bed for Brick, Stone Block, Wood Block, Asphalt Block and Other Block Pavements.

STANDARD METHODS

C 31 – 27. Of Making and Storing Specimens of Concrete in the Field.
C 39 – 27. Of Making Compression Tests of Concrete.
C 42 – 27. Of Securing Specimens of Hardened Concrete from the Structure.
C 29 – 27. Of Test for Unit Weight of Aggregate for Concrete.

*C 30 – 22. Of Test for Determination of Voids in Fine Aggregate for Concrete.
C 40 – 27. Of Test for Organic Impurities in Sands for Concrete.
C 41 – 24. Of Test for Sieve Analysis of Aggregates for Concrete.
D 30 – 18. Of Test for Apparent Specific Gravity of Coarse Aggregates.
D 55 – 25. Of Test for Apparent Specific Gravity of Sand, Stone and Slag Screenings, and Other Fine Non-Bituminous Highway Materials.

BRICKS AND REFRACTORIES

STANDARD SPECIFICATIONS

C 7 – 15. For Paving Brick.
C 32 – 24. For Clay Sewer Brick.

STANDARD METHODS

C 16 – 20. Of Test for Refractory Materials Under Load at High Temperatures.
C 20 – 20. Of Test for Porosity and Permanent Volume Changes in Refractory Materials.
C 24 – 20. Of Test for Softening Point of Fire-Clay Brick.
C 18 – 21. Of Ultimate Chemical Analysis of Refractory Materials, Including Chrome Ores and Chrome Brick.

STANDARD DEFINITIONS

C 27 – 20. For Clay Refractories.

PIPE AND DRAIN TILE

STANDARD SPECIFICATIONS

C 13 – 24. For Clay Sewer Pipe.
C 14 – 24. For Cement-Concrete Sewer Pipe.
†C 4 – 24. For Drain Tile.

STANDARD DEFINITIONS

C 8 – 24. Of Terms Relating to Sewer Pipe.

RECOMMENDED PRACTICE

C 12 – 19. For Laying Sewer Pipe.

HOLLOW TILE

STANDARD SPECIFICATIONS

C 34 – 27. Specifications and Tests for Hollow Burned-Clay Load-Bearing Wall Tile.
C 57 – 27. Specifications and Tests for Hollow Burned-Clay Floor Tile.

STANDARD DEFINITIONS

C 43 – 24. Of Terms Relating to Hollow Tile.

* Approved as "Tentative American Standard" by the American Engineering Standards Committee.
† Approved as "American Standard" by the American Engineering Standards Committee.

MISCELLANEOUS SUBJECTS

STANDARD SPECIFICATIONS

E 11 – 26. *For Sieves for Testing Purposes.*

STANDARD DEFINITIONS

E 12 – 27. *Of Terms Relating to Specific Gravity.*

D. MISCELLANEOUS MATERIALS

PRESERVATIVE COATINGS

STANDARD SPECIFICATIONS

D 234 – 27. For Raw Linseed Oil.
D 125 – 23. For Perilla Oil, Raw or Refined.
D 13 – 26. For Gum Spirits of Turpentine and Steam-Distilled Wood Turpentine.
D 236 – 27. For Destructively Distilled Wood Turpentine.
D 207 – 26. For Dry Bleached Shellac.
D 237 – 27. For Orange Shellac.
D 79 – 24. For Zinc Oxide.
D 80 – 24. For Leaded Zinc Oxide.
D 81 – 24. For Basic Carbonate White Lead.
D 82 – 24. For Basic Sulfate White Lead.
D 83 – 24. For Red Lead.
D 84 – 27. For Mineral Iron Oxide.
D 85 – 27. For Ocher.
D 208 – 26. For Lithopone.
D 209 – 26. For Lampblack.
D 210 – 26. For Bone Black.
D 211 – 27. For Chrome Yellow.
D 212 – 27. For Pure Chrome Green.
D 213 – 27. For Reduced Chrome Green.

STANDARD METHODS

D 233 – 26. Of Sampling and Testing Turpentine.
D 153 – 27. Of Test for Specific Gravity of Pigments.
D 185 – 26. Of Test for Coarse Particles in Paint Pigments.
D 154 – 25. Of Testing Oleo-Resinous Varnishes.
D 29 – 25. Of Testing Shellac.
*D 56 – 21. Of Test for Flash Point of Volatile Flammable Liquids.
*D 34 – 27. Of Routine Analysis of White Pigments.
*D 49 – 27. Of Routine Analysis of Dry Red Lead.
*D 50 – 27. Of Routine Analysis of Yellow, Orange, Red and Brown Pigments Containing Iron and Manganese.
D 126 – 27. Of Routine Analysis of Yellow and Orange Pigments Containing Chromium Compounds, Blue Pigments and Chrome Green.
D 186 – 27. Of Routine Analysis of Titanium Pigments.

STANDARD DEFINITIONS

D 16 – 24. Of Terms Relating to Paint Specifications.

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* Approved as "Tentative American Standard" by the American Engineering Standards Committee.

PETROLEUM PRODUCTS AND LUBRICANTS

See also **Road Materials** and **Waterproofing and Roofing Materials**

STANDARD METHODS

D 206 – 25. Abridged Volume Correction Table for Petroleum Oils.
D 128 – 27. Of Analysis of Grease.
D 187 – 27. Of Test for Burning Quality of Kerosine Oils.
D 219 – 27. Of Test for Burning Quality of Long-Time Burning Oil for Railway Use.
D 239 – 27. Of Test for Burning Quality of Mineral Seal Oil.
D 86 – 27. Of Test for Distillation of Gasoline, Naphtha, Kerosine, and Similar Petroleum Products.
D 216 – 27. Of Test for Distillation of Natural Gas Gasoline.
D 117 – 27. Of Testing Electrical Insulating Oils.
D 56 – 21. Of Test for Flash Point of Volatile Flammable Liquids.
D 93 – 22. Of Test for Flash Point by Means of the Pensky-Martens Closed Tester.
D 92 – 24. Of Test for Flash and Fire Points by Means of Open Cup.
D 87 – 22. Of Test for Melting Point of Paraffin Wax.
D 157 – 27. Of Test for Steam Emulsion of Lubricating Oils.
D 129 – 27. Of Test for Sulfur in Petroleum Oils Heavier than Illuminating Oil.
D 240 – 27. Of Test for Thermal Value of Fuel Oil.
D 88 – 26. Of Test for Viscosity of Petroleum Products and Lubricants.
D 95 – 27. Of Test for Water in Petroleum Products and Other Bituminous Materials.
D 96 – 24. Of Test for Water and Sediment in Petroleum Products by Means of Centrifuge.

ROAD MATERIALS

STANDARD SPECIFICATIONS

*D 57 – 20. For Materials for Cement Grout Filler for Brick and Stone Block Pavements.
D 58 – 24. For Materials for Cement Mortar Bed for Brick, Stone Block, Wood Block, Asphalt Block and Other Block Pavements.
C 7 – 15. For Paving Brick.
D 59 – 26. For Block for Granite Block Pavements.
D 131 – 23. For Block for Recut Granite Block Pavements.
D 132 – 23. For Block for Durax Granite Pavements.
D 52 – 20. For Wooden Paving Blocks for Exposed Pavements.
D 65 – 23. For Broken Slag for Waterbound Base and Wearing Course.
D 66 – 23. For Shovel-Run or Crusher-Run Broken Slag for Waterbound Base.
D 195 – 27. For Broken Slag for Bituminous Macadam Base.
D 196 – 27. For Broken Slag for Bituminous Concrete Base.
D 159 – 27. For Broken Slag for Bituminous Macadam Wearing Course.

* Approved as "Tentative American Standard" by the American Engineering Standards Committee.

D 160 – 27. For Broken Slag for Bituminous Concrete (Coarse-Graded Aggregate Type).
D 161 – 27. For Broken Slag for Bituminous Concrete (Fine-Graded Aggregate Type).
E 11 – 26. For Sieves for Testing Purposes.

STANDARD METHODS

D 2 – 26. Of Test for Abrasion of Rock.
*D 3 – 18. Of Test for Toughness of Rock.
*D 30 – 18. Of Test for Apparent Specific Gravity of Coarse Aggregates.
D 55 – 25. Of Test for Apparent Specific Gravity of Sand, Stone and Slag Screenings, and Other Fine Non-Bituminous Highway Materials.
D 72 – 21. Of Test for Quantity of Clay and Silt in Gravel for Highway Construction.
*D 75 – 22. Of Sampling Stone, Slag, Gravel, Sand and Stone Block for Use as Highway Materials, Including Some Material Survey Methods.
D 7 – 27. Of Mechanical Analysis of Sand or Other Fine Highway Material, Except Fine Aggregates Used in Cement Concrete.
D 18 – 16. Of Mechanical Analysis of Broken Stone or Broken Slag, Except Aggregates Used in Cement Concrete.
D 19 – 16. Of Mechanical Analysis of Mixtures of Sand or Other Fine Material with Broken Stone or Broken Slag, Except Aggregates Used in Cement Concrete.
D 35 – 18. Form of Specifications for Certain Commercial Grades of Broken Stone.
D 4 – 27. Of Test for the Determination of Bitumen.
D 165 – 27. Of Test for the Determination of Proportion of Bitumen Soluble in Carbon Tetrachloride.
D 6 – 27. Of Test for Loss on Heating of Oil and Asphaltic Compounds.
D 5 – 25. Of Test for Penetration of Bituminous Materials.
D 36 – 26. Of Test for Softening Point of Bituminous Materials (Ring-and-Ball Method).
D 61 – 24. Of Test for Softening Point of Tar Products (Cube-in-Water Method).
D 139 – 27. Of Float Test for Bituminous Materials.
D 70 – 27. Of Test for Specific Gravity of Road Oils, Road Tars, Asphalt Cements and Soft Tar Pitches.
D 71 – 27. Of Test for Specific Gravity of Asphalts and Tar Pitches Sufficiently Solid to be Handled in Fragments.
D 140 – 25. Of Sampling Bituminous Materials.
D 95 – 27. Of Test for Water in Petroleum Products and Other Bituminous Materials.

STANDARD DEFINITIONS

D 8 – 18. Of Terms Relating to Materials for Roads and Pavements.
E 12 – 27. Of Terms Relating to Specific Gravity.

* Approved as "Tentative American Standard" by the American Engineering Standards Committee.

COAL AND COKE

STANDARD SPECIFICATIONS

D 17 – 16. For Foundry Coke.
D 166 – 24. For Gas and Coking Coals.

STANDARD METHODS

*D 21 – 16. Of Sampling Coal.
D 271 – 27. Of Laboratory Sampling and Analysis of Coal and Coke.
D 141 – 23. Of Shatter Test for Coke.
D 167 – 24. Of Test for Volume of Cell Space of Lump Coke.

STANDARD DEFINITIONS

D 121 – 27. Of Terms Relating to Coal and Coke.

TIMBER AND TIMBER PRESERVATIVES

STANDARD SPECIFICATIONS

D 245 – 27. For Structural Wood Joist, Planks, Beams, Stringers and Posts
D 25 – 20. For Southern Yellow-Pine Piles and Poles to be Creosoted.
D 52 – 20. For Wooden Paving Blocks for Exposed Pavements.

STANDARD METHODS

D 143 – 27. Of Testing Small Clear Specimens of Timber.
D 198 – 27. For Conducting Static Tests of Timber in Structural Sizes.
D 38 – 27. Of Sampling and Analysis of Creosote Oil.
D 168 – 27. Of Test for Coke Residue of Creosote Oil.
D 199 – 27. Of Chemical Analysis of Zinc Chloride.

STANDARD DEFINITIONS

D 9 – 15. Of Terms Relating to Structural Timber.

WATERPROOFING AND ROOFING MATERIALS

STANDARD SPECIFICATIONS

D 40 – 25. For Asphalt for Use in Damp-proofing and Waterproofing Below Ground Level.
D 144 – 25. For Asphalt for Use in Damp-proofing and Waterproofing Above Ground Level.
D 41 – 26. For Primer for Use with Asphalt in Damp-proofing and Waterproofing Below and Above Ground Level.
D 42 – 25. For High-Carbon Coal-Tar Pitch for Use in Damp-proofing and Waterproofing Below Ground Level.
D 145 – 25. For High-Carbon Coal-Tar Pitch for Use in Damp-proofing and Waterproofing Above Ground Level.
D 200 – 25. For High-Bitumen Coal-Tar Pitch for Use in Damp-proofing and Waterproofing Below Ground Level.

* Approved as "Tentative American Standard" by the American Engineering Standards Committee.

D 201 – 25. For High-Bitumen Coal-Tar Pitch for Use in Damp-proofing and Waterproofing Above Ground Level.
D 251 – 27. For High-Carbon Coal-Tar Pitch for Use in Constructing Built-Up Roofs Surfaced with Slag or Gravel.
D 252 – 27. For High-Bitumen Coal-Tar Pitch for Use in Constructing Built-Up Roofs Surfaced with Slag or Gravel.
D 43 – 25. For Creosote Oil for Priming Coat with Coal-Tar Pitch in Damp-proofing and Waterproofing Below and Above Ground Level.
D 169 – 25. For Asphalt Mastic for Use in Waterproofing.
D 170 – 25. For Bituminous Grout for Use in Waterproofing Above Ground Level.
D 171 – 25. For Bituminous Grout for Use in Waterproofing Below Ground Level.
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LIST OF A.S.T.M. TENTATIVE STANDARDS

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Published collectively in their latest revised form in 1927 BOOK OF A.S.T.M. TENTATIVE STANDARDS. Tentative Standards are also published in the annual Proceedings, Part I, in the year in which they were submitted or last revised as indicated by the final number of their serial designation.

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A 67 – 26 T. For Steel Tie Plates.
A 77 – 20 T. For Electric Cast-Steel Anchor Chain.
A 113 – 27 T. For Structural Steel for Locomotives and Cars.
A 114 – 27 T. For Marine Boiler Steel Plates.
A 95 – 26 T. For Carbon-Steel Castings for Valves, Flanges, and Fittings for High-Temperature Service.
A 105 – 27 T. For Forged or Rolled Steel Pipe Flanges for High-Temperature Service.

[1] To replace, when adopted, the present Standard Specifications for Steel Track Spikes (Serial Designation: A 65 – 24).

A 106 – 27 T. For Lap-Welded and Seamless Steel Pipe for High-Temperature Service.
A 109 – 27 T. For Cold-Rolled Strip Steel.
A 115 – 27 T. For Alloy Tool Steel.
A 111 – 27 T. For Zinc-Coated (Galvanized) Iron or Steel Telephone and Telegraph Line Wire.
A 112 – 27 T. For Zinc-Coated (Galvanized) Iron or Steel Tie Wires.
A 116 – 27 T. For Zinc-Coated (Galvanized) Wire Fencing.
A 117 – 27 T. For Zinc-Coated Chain-Link Fence Fabric Galvanized After Weaving.
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A 34 – 27 T. Of Test for Magnetic Properties of Iron and Steel at Low Inductions for Audio and Power Frequencies.[1]
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B 26 – 26 T. For Aluminum Base Alloy Sand Castings.
D 27 – 21 T. For Insulated Wire and Cable: 30-per-cent Hevea Rubber.
B 9 – 27 T. For Bronze Trolley Wire.
B 59 – 26 T. For Aluminum Bronze Castings.
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B 62 – 26 T. For Composition Brass or Ounce Metal Sand Castings.
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B 66 – 27 T. For Bronze Castings in the Rough for Locomotive Wearing Parts.
B 67 – 27 T. For Car and Tender Journal Bearings, Lined.
B 24 – 26 T. For Aluminum Ingots for Remelting.

[1] To be added, when adopted, to the present Standard Methods of Test for Magnetic Properties of Iron and Steel (Serial Designation: A 34 – 27).

B 25 – 26 T. For Aluminum Sheet.
B 68 – 27 T. For Copper Tubing for Refrigerators.
B 69 – 27 T. For Rolled Zinc.
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B 70 – 27 T. Of Test for Change of Resistance with Temperature of Metallic Materials for Electrical Heating.
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[1] To be added, when adopted, to the present Standard Specifications and Tests for Portland Cement (Serial Designation: C 9 – 26).

[2] To be added, when adopted, to the present Standard Definitions of Terms Relating to the Gypsum Industry (Serial Designation: C 11 – 26).

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[1] To replace, when adopted, the present Standard Specifications for Paving Brick (Serial Designation: C 7 – 15).

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* Approved as "Tentative American Standard" by the American Engineering Standards Committee.

[1] To be added, when adopted, to the present Standard Methods of Testing Oleo-Resinous Varnishes (Serial Designation: D 154 – 25).

[2] To be added, when adopted, to the present Standard Methods of Testing Shellac (Serial Designation: D 29 – 25).

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[1] To be added, when adopted, to the present Standard Methods of Laboratory Sampling and Analysis of Coal and Coke (Serial Designation: D 271 – 27).

[2] To be added, when adopted, to the present Standard Definitions of Terms Relating to Coal and Coke (Serial Designation: D 121 – 27).

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[1] To be added, when adopted, to the present Standard Definitions of Terms Relating to Textile Materials (Serial Designation: D 123 – 27).

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RECOMMENDATIONS FOR MEMBERSHIP

AMERICAN SOCIETY FOR TESTING MATERIALS,
1315 Spruce Street,
Philadelphia, Pa.

Dear Sirs:

The undersigned recommends the following persons (or corporations, firms, etc.) for membership in the Society. It is suggested that you send them general information concerning the Society as well as application blanks for membership.

(In case of a firm, corporation, etc., indicate the name and title of the officer who should be addressed.)

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Yours truly,

(Signed).....
Member, Am. Soc. Testing Mats.

Date.....

1927 B. S., I

American Society for Testing Materials

Application for Membership

THE UNDERSIGNED HEREBY APPLIES FOR { CORPORATE / INDIVIDUAL / JUNIOR } MEMBERSHIP IN THE AMERICAN SOCIETY FOR TESTING MATERIALS. IF THIS APPLICATION BE DULY APPROVED, HE AGREES TO BE GOVERNED BY THE CHARTER AND BY-LAWS OF THE SOCIETY AND TO FURTHER ITS OBJECTS AS LAID DOWN THEREIN.

NAME.....
(FIRM, ORGANIZATION OR INDIVIDUAL APPLICANT)

ADDRESS.....

.....

NATURE OF BUSINESS.....

IF CORPORATE MEMBERSHIP, NAME AND TITLE OF INDIVIDUAL WHO WILL EXERCISE MEMBERSHIP PRIVILEGES:

NAME..... TITLE.....

IF PERSONAL MEMBERSHIP, NAME OF ORGANIZATION WITH WHICH APPLICANT IS AFFILIATED AND OFFICIAL TITLE OR OCCUPATION:

NAME OF ORGANIZATION.....

ADDRESS OF ORGANIZATION.....

APPLICANT'S TITLE OR OCCUPATION.....

IF JUNIOR MEMBERSHIP GIVE DATE OF BIRTH.....

RECOMMENDED BY (TWO MEMBERS) .....
.....

[Application for membership should be mailed to AMERICAN SOCIETY FOR TESTING MATERIALS, 1315 Spruce Street, Philadelphia, Pa.]

1927 B. S., I

American Society for Testing Materials

Extract from Charter

1. The name of the proposed corporation is the "American Society for Testing Materials."

2. The corporation is formed for the promotion of knowledge of the materials of engineering, and the standardization of specifications and the methods of testing.

Extract from By-Laws

Article I. Members

Section 1. The Society shall consist of Members, Junior Members, Student Members, and Honorary Members.

Sec. 2. A Member shall be a person, or a corporation, a firm, a technical or scientific society, a teaching faculty, or a library, proposed by two members and approved by the Executive Committee.

Sec. 3. A Junior Member shall be a person less than twenty-seven years of age on the date of his admission, proposed by two members and approved by the Executive Committee. A Junior Member shall have the same rights and privileges as a Member, except that he shall not be eligible for office, and his status shall be changed from that of Junior Member to Member at the beginning of the fiscal year next succeeding the date on which he attains the age of twenty-seven years. * * *

Article V. Meetings

Section 1. The Society shall meet annually at a time and place fixed by the Executive Committee.

Sec. 2. Special meetings may be called whenever the Executive Committee shall deem it necessary, or upon the request in writing to the President of twenty-five (25) members.

Article VII. Dues

Section 1. The fiscal year shall commence on the first day of January. The annual dues, payable in advance, shall be as follows: For Members that are companies, firms, corporations, industrial associations or commercial testing laboratories, $30; for all other Members, $15; for Junior Members, $7.50; for Student Members, $3. Honorary Members shall not be subject to dues.[1]

Sec. 2. The entrance fees, payable on admission to the Society, shall be $10 for Members and $5 for Junior Members. The transfer fee, payable upon transfer from one grade of membership to another, shall be the difference between the corresponding entrance fees; provided that the payment of such transfer fee shall not be required of any Junior Member holding membership at the date of adoption of this section.

Sec. 5. Any person elected after six months of any fiscal year shall have expired, may pay only one-half of the amount of dues for that fiscal year; but in that case he shall not be entitled to a copy of the Proceedings for the current year.

[1] This Section of the By-laws was adopted September 1, 1927, to become effective January 1, 1928. Until the latter date the annual dues will continue to be: For Members (whether company or individual), $15; for Junior Members, $7.50; for Student Members, $3.

American Society for Testing Materials

Application for Student Membership

THE UNDERSIGNED HEREBY APPLIES FOR STUDENT MEMBERSHIP IN THE AMERICAN SOCIETY FOR TESTING MATERIALS AND ENCLOSES A REMITTANCE OF THREE DOLLARS IN PAYMENT OF THE CURRENT YEAR'S DUES. IF THIS APPLICATION BE DULY APPROVED, HE AGREES TO BE GOVERNED BY THE CHARTER AND BY-LAWS OF THE SOCIETY AND TO FURTHER ITS OBJECTS AS LAID DOWN THEREIN.

NAME OF APPLICANT .....

STUDENT IN (COURSE) .....

AT (NAME AND ADDRESS OF SCHOOL) .....

.....

YEAR (CHECK) JUNIOR, SENIOR OR GRADUATE

DATE OF BIRTH .....

ADDRESS FOR MAIL .....

.....

PROPOSED BY:

(SIGNED) .....

(TITLE) .....

MEMBER OF FACULTY

[Application for membership should be mailed to AMERICAN SOCIETY FOR TESTING MATERIALS, 1315 Spruce Street, Philadelphia, Pa.]

1927 B. S., I

American Society for Testing Materials

Extract from Charter

1. The name of the proposed corporation is the "American Society for Testing Materials."

2. The corporation is formed for the promotion of knowledge of the materials of engineering, and the standardization of specifications and the methods of testing.

Extract from By-Laws

Article I. Members

Section 1. The Society shall consist of Members, Junior Members, Student Members, and Honorary Members.

Sec. 2. A Member shall be a person, or a corporation, a firm, a technical or scientific society, a teaching faculty or a library, proposed by two members and approved by the Executive Committee.

Sec. 3. A Junior Member shall be a person less than twenty-seven years of age on the date of his admission, proposed by two members and approved by the Executive Committee. A Junior Member shall have the same rights and privileges as a Member, except that he shall not be eligible for office, and his status shall be changed from that of Junior Member to Member at the beginning of the fiscal year next succeeding the date on which he attains the age of twenty-seven years. * * *

Sec. 4. A Student Member shall be a Junior, Senior or Graduate Student in a technical school of recognized standing, or a student not over twenty-five years of age engaged in technical studies in an apprentice course or night school, proposed by a member of the faculty and elected by the Executive Committee.

A Student Member shall have such rights and privileges as may be determined by the Executive Committee and he shall not be eligible for office. His status shall be changed to that of Junior Member or Member upon severance of his connection with the technical school, apprentice course or night school.

Article V. Meetings

Section 1. The Society shall meet annually at a time and place fixed by the Executive Committee.

Sec. 2. Special meetings may be called whenever the Executive Committee shall deem it necessary, or upon the request in writing to the President of twenty-five (25) members.

Article VII. Dues

Section 1. The fiscal year shall commence on the first day of January. The annual dues, payable in advance, shall be as follows: For Members that are companies, firms, corporations, industrial associations or commercial testing laboratories, $30; for all other Members, $15; for Junior Members, $7.50; for Student Members, $3. Honorary Members shall not be subject to dues.[1]

Sec. 2. The entrance fees, payable on admission to the Society, shall be $10.00 for Members and $5.00 for Junior Members. The transfer fee, payable upon transfer from one grade of membership to another, shall be the difference between the corresponding entrance fees; provided that the payment of such transfer fee shall not be required of any Junior Member holding membership at the date of adoption of this section.

Resolution Adopted by Executive Committee

The Student Members shall receive the Year Book, Bulletins and other circular material, preprints upon the same basis as other members, and the triennial Book of Standards with the intervening annual supplements. Student Members shall have the privilege of other members of the Society of obtaining Society publications at special prices to members.

[1] This Section of the By-laws was adopted September 1, 1927, to become effective January 1, 1928. Until the latter date the annual dues will continue to be: For Members (whether company or individual), $15; for Junior Members, $7.50; for Student Members, $3.

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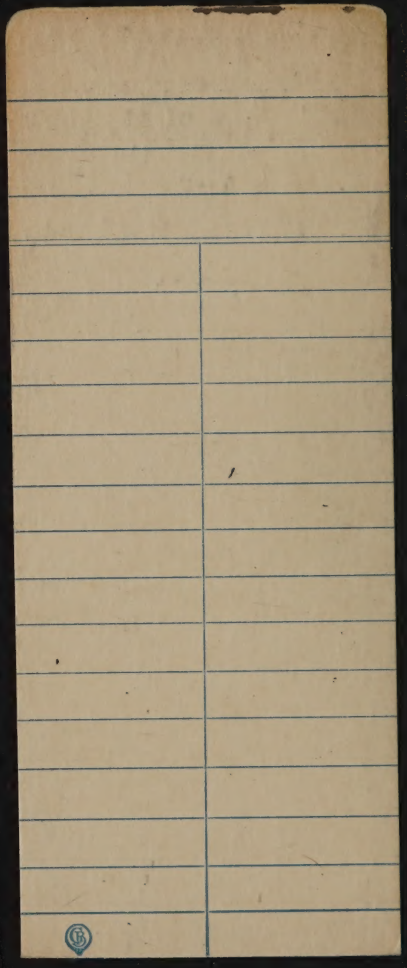

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